Rapid Automatized Naming as a Predictor of Children's Reading Performance: What Is the Role of Inattention?

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RAPID AUTOMATIZED NAMING AS A PREDICTOR OF CHILDREN’S
READING PERFORMANCE: WHAT IS THE ROLE OF INATTENTION?

By

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With love and gratitude to my aunt, Ruth Munitch
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ABSTRACT

The purpose of this study was to determine if children’s performance on rapid automatic naming (RAN) tasks served as a mediator in the relation between inattention and reading. Although previous studies have produced mixed results when examining the relation between naming performance and ADHD, ADHD has typically been defined using DSM IIIR or DSM IV criteria, which do not require individuals to evidence symptoms of inattention. This study expands the literature by focusing on inattention, the component of ADHD that has been shown to be most related to reading. Children from second to fourth grade classrooms completed two individual testing sessions which included assessment of their phonological awareness, naming (RAN-letters, RAN-digits, RAN-objects, RAN-colors), and reading ability. Inattention was assessed using both the Conners Continuous Performance Task (CPT; Conners, 2000) and parent ratings. Relations between inattention, naming, phonological awareness and reading were examined using correlation and hierarchical regression analyses. Consistent with previous research, performance on RAN-letters and RAN-digits, but not performance on RAN-objects and RAN-colors, was related to children’s scores on reading measures. Although CPT performance was associated with phonological awareness in this study, neither performance on the CPT nor parent-ratings of attention was associated with children’s performance on the RAN tasks. Consequently, the results of this study failed to find support for the hypothesis that naming performance mediates the relation between inattention and reading outcomes.
The prevalence of reading disabilities in American school-age children has been estimated to range from 3.7 to 7.8 percent (American Psychiatric Association, 2000; Badian, 1984, 1999; Shaywitz, Shaywitz, Fletcher, & Escobar, 1990). The Diagnostic and Statistical Manual of Mental Disorders has estimated that approximately four percent of children suffer from a reading disability, with males significantly more likely to be identified and diagnosed. Reading disabilities represent one type of learning disability or learning disorder and are marked by reading achievement that is significantly less than expected given an individual’s chronological age, measured intelligence, and education (DSM-IV; American Psychiatric Association, 2000). Children with learning disabilities report lower levels of global self-worth and lower levels of perceived confidence in academic domains (Boetsch, Green & Pennington, 1996) and are more likely to be rejected or ignored by their classmates as compared to children without learning disabilities (Estell, Jones, Pearl, Van Acker, Farmer, & Rodkin, 2008; Frederickson & Furnham, 2004; Kavale & Forness, 1996; Stone & La Greca, 1990).

Consequences of reading disabilities, specifically, include decreased academic achievement overall, with a related narrowing in career options (Gottfredson, Finucci, & Childs, 1984; Michelsson, Byring, & Bjoerkgren, 1985). Moreover, children with reading disabilities have a significantly higher likelihood of being diagnosed with psychiatric disorders such as anxiety, depression, conduct disorder, and attention-deficit hyperactivity disorder compared to their non-reading disabled peers (Arnold, Goldston, Walsh, Reboussin, Daniel, Hickman et al., 2005; Boetsch et al., 1996; Carroll, Maughan, Goodman, & Meltzer, 2005; Willcutt & Gaffney-Brown, 2004; Willcutt & Pennington, 2000; although see Miller, Hynd, & Miller, 2005). Adolescents with significant reading difficulties are at increased risk of suicidal ideation, suicide attempts, and school dropout, compared to their peers with typical reading achievement (Daniel, Walsh, Goldston, Arnold, Reboussin & Wood, 2009).

Children with reading disabilities (RD) are at an increased risk of exhibiting symptoms consistent with Attention Deficit Hyperactivity Disorder (ADHD) (e.g., August & Garfinkel,
1990; Carroll et al., 2005; Cantwell & Baker, 1991; Cantwell & Satterfield, 1978; Dykman & Ackerman, 1991; Hinshaw, 1992; Schuerholz et al., 1995; Willcutt & Pennington, 2000; Willcutt, Pennington, Olson & DeFries, 2007). The prevalence of ADHD in samples of RD children ranges from 25% to 40% (Willcutt & Pennington, 2000) whereas the prevalence of RD in samples of ADHD children ranges from 15% to 26% (Willcutt & Pennington, 2000). It is unclear which factors are responsible for the high level of comorbidity between reading disabilities and ADHD. One view is that the overlap between the two disorders is the result of a shared genetic etiology (e.g., Gillis, Gilger, Pennington, & DeFries, 1992; Light, Pennington, Gilger, & DeFries, 1995; Stevenson et al., 2005; Stevenson, Pennington, Gilger, DeFries & Gillis, 1993; Willcutt, Pennington, & DeFries, 2000; Willcutt et al., 2002; Willcutt et al., 2007). Stevenson et al. (1993) examined same-sex twin pairs and estimated that shared genetic influence was responsible for approximately 75% of the comorbidity between ADHD and spelling disability. Similarly, Levy, Hay, McLaughlin & Wood (1996) contrasted twins with non-twin siblings and found a significant association between ADHD and speech and reading problems in their twin sample. Willcutt et al. (2002) showed that the same genetic influences contribute to both ADHD and RD. These researchers isolated a chromosome (i.e., chromosome 6p) that they believed contributed to comorbidity between the two disorders. In contrast, although Gilger, Pennington, and DeFries (1992) found higher concordance rates between RD and ADHD within their monozygotic versus dizygotic twin pairs, this difference was not statistically significant.

Numerous studies suggest that RD and ADHD are separate disorders in that each disorder predicts unique higher level functions (e.g., Bental & Tirosh, 2007; Hall, Halperin, Schwartz, & Newcorn, 1997; Klorman et al., 1999; Marzocchi et al., 2008; Pennington, Groisser & Welsh, 1993; Purvis & Tannock, 2000; Roodenrys, Koloski & Grainger, 2001; Rucklidge & Tannock, 2002; Swanson, Mink & Bocian, 1999; Weiler, Holmes Bernstein, Bellinger, & Waber, 2000; Willcutt et al., 2001). Weiler et al. (2000) contrasted an ADHD group, an RD group, and an ADHD-RD group on two measures of processing speed. Their results showed that children with ADHD performed more poorly on a visual search task as compared to an auditory processing task; the opposite pattern of results was found for subjects with RD. Klorman et al. (1999) contrasted groups of ADHD-combined type, ADHD-primarily inattentive type, ADHD-combined plus RD, and ADHD-primarily inattentive type plus RD. Deficits in executive
functioning as measured by a puzzle task and card sort task were observed only for children classified as ADHD-combined type and were thus independent of RD. Swanson et al. (1999) found visual-spatial working memory to be a weakness for children with RD. Children with RD performed the same as children with ADHD on tasks assessing phonological processing skill, however. Swanson et al.’s most interesting finding was that verbal working memory was a weakness for children with RD relative to children who were diagnosed with both RD and ADHD, thus suggesting that the effects of RD are not additive with the effects of ADHD. Rather each group has a unique phenotypic presentation. Finally, Marzocchi et al. (2008) showed that children with ADHD performed significantly worse than children with RD on tasks involving planning (i.e., Tower of London; Krikorian, Bartok, & Gay, 1994).

An alternative way to conceptualize the ADHD-RD link is to determine if there is a causal relation between the two disorders. That is, children with attention problems may have difficulty learning to read because they are unable to remain focused on tasks such as learning letter sounds and sounding out words. Conversely, children experiencing difficulty with reading may become fidgety and demonstrate off-task classroom behavior as a result of reading-related frustration. Whereas McGee and Share (1988) tentatively concluded that learning difficulties lead to ADHD, a number of studies suggest that ADHD and inattention are predictive of reading difficulties (e.g., Dally, 2006; Fergusson & Horwood, 1992; Rabiner, Coie, & the Conduct Problems Prevention Research Group, 2000). In a large study of a New Zealand birth cohort, Fergusson and Horwood (1992) determined that children’s level of attention deficit at age 12 influenced their reading achievement at that same age. Rabiner et al. (2000) followed children from kindergarten to fifth grade and found attention to play a role in the development of reading difficulties across time. Similarly, Dally (2006) found that inattentive behavior in kindergarten had an adverse effect on first grade word identification skills and consequently second grade comprehension. Morgan, Farkas, Tufis, & Sperling (2008) found both that grade one reading difficulties led to behavioral problems in third grade and that poor task engagement in first grade was associated with third grade reading problems. Willcutt, Betjemann, et al. (2007) examined preschoolers and found a significant association between parent-rated ADHD and pre-reading skills. Conversely, Velting and Whitehurst (1997) were unable to find a causal relation between reading related skills and inattentive-hyperactive behavior in low-income preschool children followed to first grade.
Another approach to exploring the relation between ADHD and RD is to separate ADHD into its symptom domains (i.e., inattention, hyperactivity-impulsivity) and then determine how these independent parts relate to aspects of RD. A number of studies have shown, for example, that the inattention component of ADHD, rather than the hyperactivity-impulsivity component, is more strongly associated with reading performance. Willcutt and Pennington (2000) utilized a community sample of 8- to 18-year-old twins and found the prevalence of ADHD, inattentive type to be higher in both girls and boys with RD than in girls and boys without RD. As well, girls with RD were significantly more likely to exhibit eight of the nine symptoms of inattention but were not significantly different from girls without RD on any of the nine symptoms of Hyperactivity/Impulsivity. In comparison, boys with RD were significantly more likely to demonstrate all 18 DSM-IV symptoms of ADHD, as compared to boys without RD. Research with preschool-aged twins has similarly demonstrated that pre-reading skills are more strongly associated with symptoms of inattention than with symptoms of hyperactivity-impulsivity (Willcutt, Betjemann, et al., 2007). Moreover, preschool ratings of inattention are predictive of first grade reading abilities whereas preschool ratings of hyperactivity do not significantly predict first grade reading outcomes (Giannopulu, Escolano, Cusin, Citeau, & Dellatolas, 2008). Similarly, kindergarten inattention has been shown to be a stronger and more consistent predictor of grade five reading achievement than is kindergarten hyperactivity (Rabiner et al., 2000).

Common genetic influences accounted for 95% of the overlap between RD and inattention in a study by Willcutt et al. (2000) whereas only 21% of the overlap between RD and hyperactivity/impulsivity was due to genetic influences. Furthermore, rather than being restricted to a small subset of inattention symptoms, the relation between RD and ADHD was noted across six of the seven inattention symptoms studied. Willcutt, Pennington, et al. (2007) similarly showed that the genetic correlation between RD and ADHD was stronger for symptoms of inattention than for symptoms of hyperactivity-impulsivity. These researchers also demonstrated that the strength of the relation between reading and inattention depended upon the type of reading measure employed, with orthographic choice measures contributing substantially more variance to the prediction equation than phoneme awareness measures. More specifically, the genetic correlation between Willcutt, Pennington et al.’s (2007) inattention index and orthographic choice was .71, whereas the genetic correlation between the inattention index and phoneme awareness was .41. In contrast, the genetic correlations between the
hyperactivity/impulsivity index and the orthographic choice versus phoneme awareness measure were quite similar (i.e., .40 and .37, respectively).

Rapid Automatized Naming (RAN) tasks represent a strong candidate for understanding the relation between RD and ADHD. When administered a RAN task, participants are asked to name a series of letters, digits, colors, or objects that are lined up in a series of rows. Each type of rapid naming test contains five stimuli that belong to the same class and these five different letters, numbers, objects, or colors are arranged in a pseudorandom order in each row. In the typical task adapted from Denckla and Rudel (1974) there are five different stimuli per row and a total of 10 rows. RAN tasks are timed thus requiring participants to name the stimuli presented to them as quickly as possible. Speed of naming is significantly predictive of reading performance as will be detailed below. Accuracy of naming is typically non-predictive of reading outcomes (e.g., Compton, 2003a; Snyder & Downey, 1991; Snyder & Downey, 1995) likely due to the low error rate within speeded tasks (i.e., approximately two to four percent; Stanovich, 1981; Vellutino et al., 1996). Because RAN tasks rely upon continuous responding, children must pay attention in order to perform well (i.e., quickly). It is therefore reasonable to question whether RAN tasks may be assessing the attention component of ADHD, given the high comorbidity between RD and ADHD. Thus, given that RD is related to ADHD, and reading ability is strongly associated with RAN, it is plausible that RAN tasks are, in part, tapping attention.

In the sections that follow, evidence will first be reviewed for the role of rapid naming in the prediction of reading. This will be followed by a brief presentation of three hypotheses that have been put forth to account for the predictive utility of RAN. Next, research that has focused on the relation between ADHD and naming and whether ADHD accounts for predictive variance in naming will be examined. An evaluation of the limitations of this research will follow, concluding with the proposal that inattention, rather than ADHD, needs to be more fully explored in the prediction of naming. Finally, the purpose and hypotheses for this study will be presented.

Rapid Naming in the Prediction of Reading

An abundance of empirical evidence demonstrates that children’s speed of naming is predictive of their concurrent reading abilities (e.g., Bowers, Steffy, & Tate, 1988; Bowey, McGuigan & Ruschena, 2005; Cornwall, 1992; Georgiou, Das, & Hayward, 2008; Katzir et al., 2006; Lepola, Poskiparta, Laakkonen, & Niemi, 2005; Murphy, Pollatsek, & Well, 1988; Plaza
Cohen, 2003; Spring & Capps, 1974; Torgeson, Wagner, Simmons, & Laughon, 1990) as well as their future reading proficiency (e.g., Badian, Duffy, Als, & McNulty, 1991; Bowers & Swanson, 1991; Felton, 1992; Lambrecht Smith, Scott, Roberts, & Locke, 2008; Lepola et al., 2005; Manis, Doi, Mirsepassi, & Munoz, 1997; Mann, 1984; Meyer, Wood, Hart, & Felton, 1998; Plaza & Cohen, 2004; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Wolf, Bally, & Morris, 1986). Studies differ, however, in the proportion of variance they attribute to RAN in the prediction of reading outcome measures. In a meta-analysis by Scarborough (1988) RAN contributed an average of 14% variance to reading ability. When relevant variables such as vocabulary, letter knowledge, and phonological awareness measures were controlled, between 10% and 28% unique variance was contributed to reading outcome measures depending on the RAN task employed and the type of reading outcome measure examined (Bowers & Swanson, 1991; Manis et al., 1997). In contrast, Torgesen, Wagner and Rashotte (1994) demonstrated that RAN contributed less than 1% variance to reading outcome measures when three other phonological variables (analysis, synthesis, memory) were examined simultaneously. An examination of Torgesen et al.’s (1994) structural equation model reveals that only phonological analysis contributed significant unique variance to reading outcomes; all other variables were redundant with phonological analysis (i.e., shared variance). However, Wagner et al. (1997) subsequently determined that RAN was a significant predictor of growth in early (i.e., Kindergarten to Second Grade; First to Third Grade) as compared to later (i.e., Second to Fourth Grade) word reading skills.

RAN is predictive of a variety of reading abilities including word identification (e.g., Bowers et al., 1988; Bowey, Storey, & Ferguson, 2004; Compton, 2003b; Mann, 1984; Meyer et al., 1998; Miller et al., 2006; Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002; Schatschneider et al., 2004; Torgesen et al., 1990), reading fluency (e.g., Georgiou, Parrila & Kirby, 2006; Katzir et al., 2006; Savage & Frederickson, 2005; Schatschneider et al., 2002), reading comprehension (e.g., Katzir et al., 2006; Murphy et al., 1988) and spelling (Plaza & Cohen, 2004). Although the administration of RAN tasks appears to be quite common during kindergarten (e.g., Badian et al., 1991; Felton, 1992; Kirby, Parrila, & Pfeiffer, 2003; Mann, 1984; Wolf et al., 1986), rapid naming tasks continue to evidence predictive utility when administered in first grade (e.g., Manis et al., 1997), second grade (e.g., Bowers & Swanson, 1991; Katzir et al., 2006), and beyond (e.g., Bowey et al., 2004; Hulslander et al., 2003; Meyer et
al., 1998; Cornwall, 1992; Vukovic, Wilson, & Nash, 2004). Longitudinal studies also vary in the number of years that elapse between administration of RAN tasks and follow-up of reading-related abilities from one year (e.g., Bowers & Swanson, 1991; Manis et al., 1997; Mann, 1984) to four or more years (e.g., Badian et al., 1991; Kirby et al., 2003; Meyer et al., 1998). The predictive ability of RAN tasks remains strong even after controlling for socioeconomic status (e.g., Cornwall, 1992; Meyer et al., 1998) and verbal IQ or verbal comprehension (e.g., Bowers et al., 1988; Bowers & Swanson, 1991; Cornwall, 1992; Felton, 1992; Hulslander et al., 2003; Manis et al., 1997; Meyer et al., 1998; Torgesen et al., 1990).

RAN tasks are capable of differentiating between children with and without RD (Badian, McAnulty, Duffy, & Als, 1990; Badian et al., 1991; Denckla & Rudel, 1976; Spring & Capps, 1974) as well as between groups of skilled versus less skilled (e.g., Ackerman, Dykman, & Gardner, 1990) and poor versus average readers (e.g., Bowers & Swanson, 1991; Wolf, 1986). Significant differences have been found between individuals with RD and normal readers on RAN-digits, RAN-letters, RAN-objects, and RAN-colors. Badian et al. (1991) demonstrated, for example, that children who were classified as reading disabled in fourth grade performed significantly more poorly on all four RAN subtests at all four testing times between kindergarten and fourth grade than children who were classified as non-reading disabled. The serial nature of the RAN task appears to be central to prediction in that the speeded naming of discrete RAN stimuli has been shown to be less predictive (e.g., Wagner, Torgesen, & Rashotte, 1994) or non-predictive (e.g., Perfetti, Finger, & Hogaboam, 1978; Stanovich, 1981; Torgesen et al., 1990) of reading outcomes.

Rapid Alternating Stimulus (RAS) tests (Wolf, 1986) are a variation of RAN tests. In contrast to the RAN task, which requires participants to name 50 items from the same set (e.g., letters), the RAS task requires participants to name a letter, then a number, then a letter, constantly alternating in an ABAB (letter, number) pattern or ABCABC (letter, number, color) pattern across the 50 item set (Wolf, 1984). Although RAS tasks have not been as extensively studied as RAN tasks, research demonstrates that RAS measures are similarly predictive of concurrent (e.g., Ackerman et al., 1990; Felton, Naylor, & Wood, 1990; Wolf, 1986) and future (e.g., Wolf, 1984; 1986) reading abilities. In fact, Wolf (1984) found that a severely disabled group of second grade readers were almost unanimously unable to complete either the two set (i.e., letters and numbers) or three set (i.e., letters, numbers, and colors) Rapid Alternating
Stimulus (RAS) task in kindergarten, although they were able to name each stimulus individually and were able to perform the simpler RAN tasks.

Cross cultural research demonstrates that RAN is predictive of reading-related outcomes across a variety of languages including Dutch (e.g., Van den Bos, 1998), German (e.g., Wimmer, 1993), Hebrew (e.g., Bental & Tirosh, 2007), French (e.g., Plaza & Cohen, 2004), Finnish (e.g., Korhonen, 1995), and even Chinese, a non-alphabetic language (e.g., Chan, Hung, Liu, & Lee, 2008). Plaza and Cohen (2004), for example, determined that first grade RAN performance of French speaking children predicted second grade spelling performance, independent of phonological awareness. Similarly, Chan et al. (2008) demonstrated that rapid digit naming contributed unique variance to a literacy composite consisting of a speeded and non-speeded reading measure and spelling task. A limitation within the methodological description of several cross-language studies, however, is that researchers have not clearly specified in which language RAN tasks have been administered (e.g., Bental & Tirosh, 2007; Chan et al., 2008; Plaza & Cohen, 2004). Thus it is difficult to speculate what aspect of RAN may be responsible for reading-related outcomes in these non-English languages.

Rapid naming tasks that assess proficiency with naming numbers or letters are termed graphological tasks whereas those tasks evaluating the naming of colors or objects are labeled non-graphological tasks (Wolf et al., 1986). The predictive ability of graphological versus non-graphological RAN tasks appears to be directly related to the child’s age when completing the RAN task. Wolf et al. (1986) found that both graphological and non-graphological tasks administered in kindergarten were predictive of second grade reading performance. When these researchers examined the predictive ability of first and second grade rapid naming performance in relation to second grade reading performance, however, they discovered that only graphological tasks predicted all second grade reading measures (e.g., single word reading, connected oral reading, and comprehension). Similarly, Lambrecht Smith et al. (2008) determined that although RAN objects and colors assessed at the beginning of Kindergarten were predictive of children’s future reading, these tasks were no longer predictive when re-administered just prior to grade one. Studies which have demonstrated superior predictive power for graphological versus non-graphological tasks (e.g., Bowers et al., 1988; Compton, 2003b; Cornwall, 1992; Spring & Capps, 1974) have utilized populations of children ranging from 7 to 13 years of age. Consequently, after approximately age 6, RAN-letters and RAN-numbers tasks
appear to be superior to RAN-colors and RAN-objects tasks in the prediction of reading. There are exceptions to this, however. Meyer et al. (1998) found all four types of RAN to be predictive of reading outcomes in their longitudinal study of third to eighth graders.

Rapid naming difficulties that are identified during early childhood tend to persist into early (e.g., Korhonen, 1995) as well as middle adulthood (e.g., Felton et al., 1990). When Korhonen (1995) followed 9-year-old children to age 18, for example, he found that those subjects who were slowest at RAN and RAS at age 9 continued to have the most difficulty with speeded naming at age 18. Similarly, when Felton et al. (1990) performed a follow-up study on reading disabled adults who had experienced reading deficits as children, they found that performance on RAN and RAS measures was significantly slower than that of adult subjects who did not have a history of RD.

**Hypotheses regarding why RAN predicts Reading**

Although there is strong consensus in the reading literature regarding the value of RAN tasks to the prediction of reading, there are a variety of opinions about what is responsible for the predictive utility of RAN. Wagner, Torgesen and their colleagues (e.g., Wagner & Torgesen, 1987; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wagner et al., 1997) are the main proponents behind the notion that RAN reflects a phonological processing skill. That is, these researchers believe that speeded naming tasks assess the efficiency with which phonological codes can be accessed. Whereas several studies have demonstrated that the relation between naming and reading can be attributed to phonological skill (e.g., Bowey et al., 2005; Savage, 2004; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997) other studies have shown that RAN contributes significant variance to reading independent of phonological processes (e.g., Byrne et al., 2006; Georgiou et al., 2008; Katzir et al., 06; Kirby et al., 2003; Manis et al., 1997; Misra, Katzir, Wolf, & Poldrack, 2004; Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007).

Wolf and Bowers and colleagues (e.g., Bowers & Wolf, 1993a; Bowers & Wolf, 1993b), in contrast, believe that RAN tasks assess speed of processing, which in turn have a direct impact on the formation and retrieval of orthographic representations (i.e., memory for the visual and spelling patterns which identify individual words or word parts on the printed page; Torgesen et al., 1997). Although these researchers do not deny the importance of phonological processes, they believe that phonological skill must be assessed in conjunction with RAN to determine level of risk for reading failure. Consequently, they devised the “double deficit hypothesis” which
suggests that disabled readers may experience difficulties with phonological processes, difficulties with speeded naming, or difficulties across both of these areas. Children who fall within the double deficit category are hypothesized to have the most severe reading outcomes (i.e., deficits in all aspects of reading) whereas children who have difficulties in just one area are believed to fare much better in reading. Although a number of studies demonstrate support for this hypothesis (e.g., Biddle, Wolf, & Bowers, 1997; Bowers, 1995; Lovett, Steinbach, & Frijters, 2000; Wolf & Bowers, 1999) other research has shown that the double deficit classification system is unstable across time (Spector, 2005) or based upon a statistical artifact (Schatschneider et al., 2002).

A third area of research explores whether articulation, pause time, or both contribute significant variance to naming ability. Given that children with reading disabilities have difficulty with articulation (e.g., Ackerman et al., 1990; Avons & Hanna, 1995; Catts, 1986; 1989; Fawcett & Nicolson, 1995; Montgomery, 1981; Snowling, 1981; Snyder & Downey, 1991; Snyder & Downey, 1995) and proficiency in RAN appears to require skill with articulation, some researchers have questioned whether RAN tasks are tapping children’s competence with articulation. Research studies have generally been unable to demonstrate support for the role of articulation in naming performance (e.g., Ackerman & Dykman, 1993; Cutting & Denckla, 2001; Pennington et al., 1990). However, some evidence suggests that pause time during naming significantly predicts reading outcomes (e.g., Georgiou et al., 2006).

**ADHD in the Prediction of Naming**

The high degree of comorbidity between RD and ADHD (e.g., Willcutt & Pennington, 2000; Willcutt et al., 2000) has led some researchers to question whether RAN tasks are assessing the inattention component of ADHD. Because RAN tasks are timed and rely upon continuous responding, even very brief lapses in attention will lead to poorer scores. Sustained attention may therefore represent an important element for success on RAN tasks. Some researchers have examined the broad construct of ADHD in relation to naming whereas others have examined inattention, as will be reviewed below. Table 1 provides an overview of the types of attention constructs (e.g., ADHD, Inattention) which have been utilized within studies involving naming.
Table 1

*Attention constructs (ADHD versus Inattention) and naming measures utilized within studies exploring the relation between ADHD and naming*

<table>
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<th>Study</th>
<th>Attention Construct Assessed</th>
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<td>Ackerman &amp; Dykman (1993)</td>
<td>ADHD</td>
<td>RAN (Letters, Digits); RAS</td>
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<tr>
<td>Bental &amp; Tirosh (2007)</td>
<td>ADHD</td>
<td>RAN (Digits)</td>
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<tr>
<td>Bental &amp; Tirosh (2008)</td>
<td>ADHD</td>
<td>RAN (Digits)</td>
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<tr>
<td>Brock &amp; Christo (2003)</td>
<td>ADHD (excluded those with primarily hyperactive/impulsive symptoms)</td>
<td>Digit Naming Speed Task</td>
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<td>Brock &amp; Knapp (1996)</td>
<td>Inattention Hyperactivity</td>
<td>Digit Naming Speed Task</td>
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<td>Carte et al. (1996)</td>
<td>ADHD</td>
<td>RAN (use objects; Digits)</td>
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<tr>
<td>Chan et al. (2008)</td>
<td>Inattention</td>
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<tr>
<td>Dally (2006)</td>
<td>Inattention</td>
<td>RAN (Letters, Digits, Objects, Colors)</td>
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<td>Felton et al. (1987)</td>
<td>ADHD</td>
<td>RAN (Letter, Digits, Objects, Colors)</td>
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<tr>
<td>Felton &amp; Wood (1989)</td>
<td>ADHD</td>
<td>RAN (Letters, Digits, Objects, Colors); RAS</td>
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<td>Hinshaw et al. (2007)</td>
<td>ADHD Inattentive ADHD</td>
<td>Objects*; Digits/Letters*; accuracy assessed</td>
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<td>Hynd et al. (1991)</td>
<td>ADHD Inattentive ADHD</td>
<td>RAN (Colors) RAS</td>
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<td>Study</td>
<td>Attention Construct Assessed</td>
<td>Naming Measure(s) utilized</td>
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<td>Lonigan et al. (1999)</td>
<td>Inattention &amp; Hyperactivity</td>
<td>Objects-rhyming&lt;br&gt;Objects-nonrhyming&lt;br&gt;Size-squares &amp; circles</td>
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<td>Nigg et al. (1998)</td>
<td>ADHD</td>
<td>RAN (Objects)</td>
</tr>
<tr>
<td>Rucklidge (2006)</td>
<td>ADHD</td>
<td>RAN (Letters, Digits, Colors, Objects); RAS</td>
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<tr>
<td>Schuerholz et al. (1995)</td>
<td>Average of parent-rated Hyperactivity and Attention</td>
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<tr>
<td>Semrud-Clikeman et al. (2000)</td>
<td>ADHD</td>
<td>RAN (Letters, Digits, Colors, Objects); RAS</td>
</tr>
<tr>
<td>Tannock et al. (2000)</td>
<td>ADHD</td>
<td>RAN (Letters &amp; Colors)</td>
</tr>
<tr>
<td>Wood &amp; Felton (1994)</td>
<td>ADHD</td>
<td>RAN (Letters &amp; Digits)</td>
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Multi-group designs have been employed to investigate whether RAN performance can be best attributed to ADHD symptomology, RD symptomology, or both (e.g., Ackerman & Dykman, 1993; Felton, Wood, Brown, Campbell & Harter, 1987; Felton & Wood, 1989; Wood & Felton, 1994). Felton et al. (1987), for example, examined both graphological RAN (i.e., letters and digits) and non-graphological RAN (i.e., colors and objects) performance in 8- to 12-year-old children who were classified into four groups based upon the presence and absence of ADHD and RD (e.g., no ADHD+RD; ADHD+RD; no ADHD+no RD; ADHD+no RD). Felton et al. concluded that deficits in both graphological and non-graphological naming were specific to RD rather than ADHD. Subsequent studies utilizing this same four group methodology have demonstrated that performance by randomly selected first graders on RAS tasks (Felton & Wood, 1989) as well as fifth grade, eighth grade, and adult performance on a graphological RAN composite (Wood & Felton, 1994) are each predictive of reading status, rather than ADHD status. Similarly, Ackerman and Dykman (1993) compared graphological RAN performance as well as two-set RAS performance in their ADHD versus RD groups and found that the RD group was significantly slower on both types of naming tasks as compared to the ADHD group. This same dissociation has been replicated in populations speaking Hebrew (e.g., Bental & Tirosh, 2007) and Chinese (e.g., Chan et al., 2008).

Although the multi-group design studies reviewed above fail to support an association between naming and ADHD, a number of studies suggest that a relation exists. Lonigan et al. (1999), for example, found that RAN performance of middle-income preschoolers was significantly associated with ratings on the Inattention scale of the Conners’ Teacher Rating Scale (CTRS; Conners, 1969; 1994). Due to the young age of their subjects, however, these researchers utilized a composite of three naming tasks that differed from the typical RAN tasks (i.e., Denckla & Rudel, 1974) used in most studies. Schuerholz et al. (1995) demonstrated within their sample of children with learning disabilities that those with elevated inattention/hyperactivity difficulties were likely to perform poorest on RAN letters and digits relative to any other assessed linguistic variable. Rucklidge (2006) found that both male and female children diagnosed ADHD were significantly slower on RAN-letters, RAN-colors, and RAN-objects, relative to controls. Finally, Brock and colleagues (e.g., Brock & Christo, 2003; Brock and Knapp, 1996) showed that children with primarily inattentive ADHD performed
significantly more poorly on a digit naming speed task (i.e., Spring & Capps, 1974) relative to children without ADHD.

Another body of literature suggests that ADHD is predictive of performance on RAN-objects/colors, but is not associated with performance on RAN-letters/digits (Carte, Nigg, & Hinshaw, 1996; Nigg, Hinshaw, Carte, and Treuting, 1998; Semrud-Clikeman, Guy, Griffin, and Hynd, 2000; Tannock, Martinussen, & Frijters, 2000). Carte et al. (1996), for example, demonstrated that 6- to 12-year-old children with ADHD performed significantly worse on RAN-objects relative to controls but no significant differences were found between groups on RAN-digits. Nigg et al. (1998) showed that children with ADHD performed significantly more slowly on RAN-objects relative to controls once the variance associated with comorbid reading and disruptive behavior problems was controlled for. Similarly, Semrud-Clikeman et al. (2000) demonstrated that children diagnosed ADHD performed significantly more slowly than controls on RAN-colors and RAN-objects. These two groups demonstrated equivalent performance on RAN-letters and RAN-digits tasks, however. Finally, Tannock et al. (2000) administered RAN-letters and RAN-colors to their ADHD, ADHD+RD, and control groups. These researchers found that the combined ADHD/RD group performed significantly more poorly on the RAN-letters task than did the ADHD group, thus implicating effects due to RD status. Both clinical groups performed significantly more poorly than the control group on the RAN-colors task, however, thus suggesting that ADHD status, rather than RD status, played a significant role in the prediction of RAN-color performance. Tannock et al. (2000) reasoned that children with ADHD experienced difficulty on RAN-colors tasks due to the vague semantic boundaries associated with this task. More specifically, it had been anticipated that more effortful processing, which is known to be a problem for children with ADHD (Barkley, 1997, as cited in Tannock et al., 2000), would be required for strong performance on the RAN-colors task. An alternative explanation, however, suggested by Tannock, Banaschewski, & Gold (2006) is that children with ADHD have decreased retinal dopamine, which impairs perception of blue/yellow stimuli, thus impacting RAN-color performance. A follow-up study demonstrated partial support for this hypothesis in that children with ADHD were found to commit significantly more blue/yellow errors but not more red/green errors than controls; however, no differences in performance were observed between groups on a Stroop naming task (Banaschewski et al., 2006).
Finally, the use of methylphenidate within naming studies contributes mixed results to an understanding of the relationship between naming and ADHD. Tannock et al. (2000), for example, demonstrated a linear effect of increasing dose of methylphenidate on color naming performance but no associated methylphenidate effect on either letter or digit naming performance. Tannock et al. viewed these results as demonstrating support for the hypothesis that RAN-color naming requires more effortful processing, a challenge for children with ADHD, as outlined above. Bental and Tirosh’s (2008) findings are at odds with Tannock et al’s conclusion, however, as Bental and Tirosh demonstrated that methylphenidate significantly improved RAN-digit naming performance.

A major consideration in the interpretation of the findings regarding the relation between ADHD and naming, reviewed above, concerns the definition and related assessment of ADHD. Within many of the studies (e.g., Felton et al., 1987; Felton & Wood, 1989; Wood & Felton, 1994; Ackerman & Dykman, 1993; Tannock et al., 2000; Semrud-Clikeman et al., 2000) ADHD was defined using DSM criteria (e.g., The Diagnostic Interview for Children and Adolescents; Herjanic, 1983). Of relevance, the two most recent versions of the DSM (DSM-IIIR, APA, 1987; DSM-IV, APA, 1994) did not require that children demonstrate symptoms of inattention to receive a diagnosis of ADHD. Rather, children who met diagnostic criteria for ADHD could have manifested a variety of problem behaviors reflecting symptoms of varying degrees of impulsivity, inattention, and/or hyperactivity. Therefore, groups of children diagnosed ADHD in the above studies may have exhibited predominately hyperactive, rather than inattentive behavior. An examination of methodology within the above reviewed studies reveals that this was sometimes the case. Felton and Wood (1989), for example, attempted to validate their parental measures of ADHD by gathering data on the Conners’ Abbreviated Rating Scales (Goyette, Conners, & Ulrich, 1978). Whereas these researchers determined that the Conners’ Abbreviated Rating Scales correlated .50 with parent measures of ADHD, examination of the Conners’ Abbreviated Rating Scales reveals that it is a 10-item Hyperactivity Index. Similarly, although Schuerholz et al. (1995) utilized the Attention Problems Scale of the CBCL, children’s scores on this measure were averaged with their scores on the Hyperactivity Index of the Conner’s Parent Rating Scale (Conners, 1978). Hence, ADHD is a descriptive label for a heterogeneous disorder that may or may not include symptoms of inattention.
Given that RD is linked to ADHD through the inattention component of ADHD (Willcutt & Pennington, 2000; Willcutt et al., 2000; Willcutt, Betjemann, et al., 2007; Willcutt, Pennington et al., 2007), it is possible that symptoms of inattention, rather than symptoms of hyperactivity/impulsivity, are more strongly related to naming performance. Indeed, findings from a number of studies suggest that the link between naming and inattention is stronger than the link between naming and hyperactivity/impulsivity. Lonigan et al. (1999), for example, found that children’s ratings on the CTRS-inattention scale, but not the CTRS-hyperactivity scale, predicted their rapid naming performance. Similarly, Brock and Knapp (1996) demonstrated that speeded digit naming was more closely associated with parent and teacher ratings of inattention as compared to parent and teacher ratings of hyperactivity. As well, Hynd et al. (1991) demonstrated that participants diagnosed primarily inattentive ADHD evidenced significantly slower performance on RAN colors as well as RAS (colors/letters/digits) relative to those diagnosed ADHD. In contrast, however, Dally (2006), found no relation between teacher ratings of inattention and naming performance. Finally, whereas Hinshaw, Carte, Fan, Jassy, & Owens (2007) found no significant difference in RAN performance between females diagnosed primarily inattentive ADHD versus ADHD-combined, this study is of limited utility in that accuracy, rather than speed of naming, was assessed.

To summarize, there is mixed evidence about whether symptoms of ADHD play a role in the prediction of naming. Although several studies have been unable to demonstrate an association between ADHD and naming, the heterogeneous nature of the ADHD construct represents a limitation within these studies. As reviewed above, participants diagnosed ADHD may or may not present with symptoms of inattention. It is precisely these inattentive symptoms of ADHD, however, that are most strongly associated with reading (e.g., Willcutt & Pennington, 2000; Willcutt et al., 2000; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005; Willcutt, Pennington, et al., 2007) and prereading skills (e.g., Willcutt, Betjemann et al., 2007). Thus, there is a need for research that focuses on the assessment of inattention specifically prior to exploring the degree to which inattention predicts naming performance.

Overview of the Present Study

The purpose of this study was to determine if performance on naming tasks serve as a mediating variable in the relation between inattention and reading ability. Whereas prior studies have produced mixed results when examining the relation between RAN performance and
ADHD, ADHD has typically been defined using DSM IIIR (American Psychiatric Association, 1987) or DSM IV (American Psychiatric Association, 1994) criteria, thus not requiring participants to evidence symptoms of inattention. A Continuous Performance Task (CPT; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956) was employed in this study, as it represents a highly sensitive direct measure of inattention that would provide a clear answer as to whether rapid naming tasks were tapping inattention. Parental ratings of children’s inattention and hyperactivity/impulsivity were also obtained to allow for comparison with inattention as assessed by CPT. As well, because rapid naming represents a speeded measure, a focus in the approach to this study was the use of both speeded and non-speeded predictor variables (e.g., phonemic awareness) as well as speeded and non-speeded reading outcome measures. The rationale was to control for the effects of rapid execution (i.e., method variance) to outcomes. Finally, the relation between length of RAN and inattention and reading, respectively, was explored in the current study.

**Study Hypotheses**

The first hypothesis was that RAN scores would significantly predict reading performance and thus replicate findings from the naming literature, as described above. Specifically, it was anticipated that performance on RAN-letters and RAN-digits would significantly predict performance on reading outcome measures, whereas performance on RAN-colors and RAN-objects was not anticipated to significantly predict reading ability. These expectations were based upon studies that have shown RAN-colors and RAN-objects (as compared to RAN-letters and RAN-digits) to lose their predictive ability beyond approximately age six (e.g., Wolf et al., 1986).

The second hypothesis was that inattention, assessed by CPT and parent ratings would significantly predict all four types of rapid naming. As reviewed above, the literature is mixed regarding the relation between naming and ADHD, perhaps because ratings of ADHD do not necessarily tap inattention, the part of ADHD that is most related to RD (e.g., Willcutt & Pennington, 2000; Willcutt et al., 2000; Willcutt, Pennington, et al., 2007). Omission errors and the hit reaction time block change index from the Conners CPT II (Conners, 2000) are sensitive to inattention but not hyperactivity, as will be reviewed below. Thus, it was reasoned that measures of inattention would significantly predict naming performance. A negative relation was expected between the CPT II omission errors variable and each of the RAN tasks. That is, it was
anticipated that as children made more omission errors and thus demonstrated poorer attention, their RAN performance would be adversely impacted. A significant negative relation was also expected between the CPT II hit reaction time block change measure and each of the four types of RAN, given that high scores on the hit reaction time block change measure reflect a slowing reaction time across the length of the test (i.e., poor sustained attention) and that this slowed reaction time was expected to similarly impact naming performance. Finally, it was anticipated that children’s RAN performance would be predicted by the Inattention scale but not the Hyperactivity-Impulsivity scale of the ADHD Rating Scale-IV: Home Version.

The third hypothesis was that phonological awareness would contribute to the prediction of RAN-letters and RAN-digits, but not contribute to the prediction of either RAN-objects or RAN-colors. These results were anticipated based on research showing that phonological awareness accounts for a large degree of variance in graphological naming (Torgesen et al., 1994) as well as studies demonstrating that phonological awareness, rapid naming, and reading outcomes are linked by a common set of genes (e.g., Byrne et al., 2006; Petrill, Deater-Deckard, Thompson, DeThorne, & Schatschneider, 2006).

The fourth hypothesis was that CPT scores would be more highly predictive of RAN performance than of performance on phonological awareness tasks (although see McGee, Clark, & Symons, 2000, below). This hypothesis was based on a need to show discriminant validity for the CPT by demonstrating that the CPT is predictive of naming performance, specifically, and not simply predictive of naming because it predicts performance on a variety of language measures including naming.

For the fifth hypothesis, it was anticipated that the speeded naming of 40 or 50 RAN symbols would correlate more highly with measures of inattention (i.e., CPT II indices and parent-rated inattention) as well as reading outcomes compared to the speeded naming of 10 or 20 RAN symbols. That is, if RAN represents a proxy for attention, it was anticipated that the lengthier the RAN task, the greater the draw on sustained attention, regardless of the specific type of RAN. In the typical RAN task (i.e., Denckla & Rudel, 1974) utilized within numerous studies, children are required to name 50 symbols comprised of 10 symbols in each of five rows. Few researchers have considered the impact of the length of the RAN task to the prediction of reading, however. In this study, each of the RAN letters, digits, objects and colors tasks consisted of five rows of symbols to be named, with 10 symbols in each row. Response times were
recorded at the end of every 10-item row, thus producing five scores for each participant (i.e., 10, 20, 30, 40 and 50-item scores) that could be contrasted for predictive utility.

The final hypothesis was that RAN performance would mediate the link between inattention as assessed by the CPT II and reading ability. That is, it was anticipated that RAN was tapping inattention and expected that inattention would significantly predict reading outcomes. For this hypothesis to have been supported four conditions needed to be met, as outlined by Baron and Kenny (1986). The first condition was that the predictor variable (i.e., Inattention, as assessed by the omission errors and Hit Reaction Time Block change indices of the CPT II and parent-rated inattention) needed to be significantly correlated with the hypothesized mediator (i.e., RAN). The second condition was that the predictor (i.e., inattention, as measured by the omission errors and Hit Reaction Time Block change indices from the CPT II, and parent-rated inattention) needed to be significantly associated with the dependent measure (i.e., composite reading score). The third condition was that the mediator (i.e., RAN) needed to be significantly associated with the dependent measure (i.e., composite reading score). The final condition was that the impact of the predictor (i.e., inattention, as measured by the omission errors and Hit Reaction Time Block change indices from the CPT II, and parent-rated inattention) on the dependent measure (i.e., composite reading score) would be reduced after controlling for the mediator.
CHAPTER 2

METHOD

Participants and Procedures

Participants

Participants from second, third and fourth grade classrooms were recruited from two English-speaking public schools representative of middle- to upper-middle class families in Winnipeg, Canada. After receiving approval from The Florida State University’s Institutional Review Board, approval from the Winnipeg Number One School Division, and permission from school administration and teachers, consent forms were sent home. As an incentive for the timely return of consent forms, each child (regardless of whether their parent agreed/declined participation) was provided a small token (e.g., glittery pencil or eraser) for return of their parental consent form. At the beginning of each day, teachers asked children if they had remembered their forms and those children who produced a parental consent form had an opportunity to choose a reward. Teachers indicated that children were excited by the reward and eager to return their forms quickly. Approximately half of study participants were recruited from four classrooms in the spring of year one and the remaining participants were recruited from many of the same classrooms in the spring of year two. In a couple instances, consent forms were distributed to only one grade in a combined grade classroom. Approximately 80% of parents who received a consent form agreed to allow their child to participate. Parents of one or two of the children from each classroom, on average, chose to not have their child participate in this study.

Overall, parents of 101 children gave consent to have their child participate in the study. Of these 101 potential participants, one child refused participation in the first year of testing and two children refused participation in year two. Two children recruited in year two had already been tested in year one, and a third child was deaf and not tested (see Dyer, Szczerbinski, MacSweeney, Green, & Campbell, 2003). Thus, a total of 95 children in second through fourth
grade participated in the study. The children, 52% male, ranged in age from 7 years, 4 months through 10 years, four months, with a mean age of approximately 8 years, 9 months (i.e., \( M = 105.42, SD = 9.75 \)).

An a priori power analysis (i.e., Cohen, 1992) indicated that a minimum of 84 participants was required to address the primary hypotheses of the study. Given this, the recruitment of 95 children was considered sufficient to achieve appropriate power. Unfortunately, many participants were missing either the ADHD parent rating scale (i.e., 8 participants) or CPT II (i.e., 9 participants) or in one case, both the ADHD rating scale and CPT II. An additional participant wished to discontinue testing after completing three language measures. This participant was not asked to return for the second (predominately CPT II) session and an ADHD questionnaire was not sent home. Whereas no significant differences were found on any demographic or completed measure when comparing participants with incomplete versus complete data (e.g., all \( p \)s from \( t \)-tests > .05), subjects with incomplete data were eliminated from analyses that included variables that these subjects were missing. To optimize power, 94 participants were included within all hierarchical regression analyses and within the partial correlation analyses that did not utilize either the ADHD parent rating scale or CPT II. Correlation analyses involving both the ADHD parent rating scale and the CPT II utilized the subjects (i.e., \( N = 77 \)) with complete data on these variables.

**Measures**

*Phonological Awareness*

Phonological awareness is a strong and stable predictor of reading ability (Bradley & Bryant, 1983; Stanovich, Cunningham, & Cramer, 1984; Wagner & Torgesen, 1987). It was therefore necessary to control for the effects of phonological awareness on reading prior to examining the role of rapid naming in reading. Both speeded and non-speeded phonological awareness were assessed to control for the effects of speed within analyses.

*Non-Speeded Phonological Awareness.* The Elision and Blending Words subtests from the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) were administered. The Elision task taps a child’s ability to say a word and then say the remaining part of the word after a specified phoneme or word sound is deleted, often resulting in
a new word or nonword. For example, participants might be instructed to say the word “meat” and then say “meat” without saying /m/. The Elision subtest contains 6 practice items and 20 test items. The Blending Words task requires the blending of isolated phonemes to form actual words. Participants listen to words presented phoneme by phoneme by audiocassette and are asked to say the words that result when the phonemes are blended together. A participant might listen to the sounds “/m/”, “/oo/”, and “/n/” and would be required to respond “moon” to receive one point. The Blending Words subtest consists of 6 practice items and 20 test items. The reliability of the Elision and Blending subtests is adequate to high across the seven to ten year-old range (Wagner et al., 1999). Wagner et al. (1999) demonstrate strong criterion-prediction validity (i.e., ranging from .61 to .74) between the Elision and Blending Words subtests, respectively, and the Word Identification and Word Analysis subtests from the Woodcock Reading Mastery Tests-Revised (Woodcock, 1987).

Speeded Phonological Awareness. The Phoneme Segmentation Fluency task from the Dynamic Indicators of Basic Early Literacy Skills (DIBELS; Kaminski & Good, 1996) was utilized to assess speeded phonological awareness in the current study. DIBELS tasks are short (i.e., one-minute), standardized fluency measures which can be used to monitor the development of pre-reading and early reading skills. The Phoneme Segmentation Fluency task assesses a participant’s ability to verbally produce individual phonemes for each three or four-phoneme word that is presented. For example, if an examiner says “sat”, a participant must respond, “/s/ /a/ /t/” to receive three possible points for this item. After a participant responds, the examiner presents the next word; the final score is based upon the number of correct phonemes produced within one minute. The Phoneme Segmentation Fluency task has been demonstrated to have strong two-week (i.e., .88; Kaminski & Good, 1996) and one-month (i.e., .79; Good, Simmons, & Kame’enui, 2001) alternate-form reliability. Concurrent criterion validity of the Phoneme Segmentation Fluency task was .54 with the Woodcock-Johnson Psycho-Educational Battery readiness cluster score in the spring of kindergarten (Good et al., 2001). The Phoneme Segmentation Fluency Task has also been shown to correlate significantly with Elision, Blending Words, and the Phonological Awareness Composite from the CTOPP, assessed in kindergarten (Hintze, Ryan, & Stoner, 2003). The predictive validity of the Phoneme Segmentation Fluency measure with the Woodcock-Johnson Psycho-Educational Battery total reading cluster score was .68, in the spring of first grade (Good et al., 2001). Although intended for use with Kindergarten
and first grade children, the Phoneme Segmentation Fluency measure was lengthened by the current author and then piloted with older children to ensure that no child reached ceiling on this measure. Thus, if necessary, an alternate form of the 24-item task was utilized in addition to the original form during the one minute testing interval. Only two participants completed the original Phoneme Segmentation Fluency measure in less than one minute and required the additional alternate form.

Rapid Automatized Naming Tasks

Children were administered RAN-letters, RAN-digits, RAN-colors, and RAN-objects tasks from the Rapid Automatized Naming and Rapid Alternating Stimulus Tests (RAN/RAS; Denckla & Wolf, 2005). RAN tasks are based on Denckla and Rudel’s classic naming tasks (1976). That is, each RAN task consisted of five items repeated in a random order, for a total of 50 stimuli, displayed in five horizontal rows of 10 items per row. As well, the specific stimuli utilized in the letters, digits, and colors tasks were identical to the stimuli employed within the original tasks; only the objects task changed. The RAN-letters task was comprised of high frequency lowercase letters (i.e., a, d, o, p, and s). The RAN-digits task consisted of single digits (i.e., 2, 4, 6, 7, and 9). The RAN-colors task consisted of high frequency colors (i.e., red, green, black, blue, yellow). Finally, the RAN-objects task consisted of common objects (i.e., book, chair, dog, hand, and star).

The RAN/RAS tasks have strong psychometric properties (Wolf & Denckla, 2005). Test-retest reliability ranges from .84 for objects to .90 for both colors and letters, respectively, to .92 for digits. With regard to concurrent validity, the RAN letters task and CTOPP rapid letter naming task correlate .71 whereas the RAN-digits task correlates .72 with the CTOPP rapid digit naming task. As well, there is a gradual decrease in the means of scores as chronological age increases. Finally, Wolf and Denckla’s review of the research literature examining concurrent relationships between RAN/RAS and reading demonstrates small to moderate correlation coefficients, with letters and numbers within the RAN/RAS tests representing better predictors of reading (word identification and reading comprehension) than colors and objects.

Before testing began, children were required to name two practice rows of five items each as the experimenter pointed to them. The instructions for each of the tasks followed Denckla and Rudel (1974). That is, each child was told, “you are going to name some things you see as fast as you can without making mistakes.” “First tell me, slowly, the names of each of
these first five things.” [Examiner pointed to each item in first row of practice items until child responded with a name for it; Examiner corrected if necessary]. “Good, now go ahead with this second (practice) row.” After flipping the page to the actual test, Examiner said, “Now we’re going to do the same thing, but there are a whole lot more items. What I want you to do, when I say ‘go’ is name every single thing you see on this page, starting with this row [Examiner swept finger across row 1] and then this row [Examiner swept finger across row 2…etc] until you come to the very last one on the page.” [Examiner then covered top part of page while giving final instructions] “Try to go as fast as you can without making any mistakes. When I lift up this paper covering this test, you’re going to start up here with the first item [Examiner pointed to the top of the page]. O.K. ready, set, Go.” A digital stopwatch was used and timing began with the child’s first word and ended with the child’s last utterance, thus causing errors and self-corrections to fall within the total time. Once timing began, no corrections were offered. Hesitations or questions were met with a “Keep Going!” response from the examiner. Total naming times (i.e., based on the number of seconds required to name the entire 50 item test) were recorded for each RAN task. Four additional time scores were recorded for each RAN task, to reflect the cumulative time that had elapsed after naming the first row (i.e., 10 items), second row (i.e., 20 items), third row (i.e., 30 items), and fourth row (i.e., 40 items). Errors were recorded, but were relatively rare and almost always self-corrected and thus were not entered into analyses.

**Reading Measures**

It was important to assess speeded as well as non-speeded reading performance to effectively control for the impact of the speeded execution of naming tasks on reading outcomes.

*Non-Speeded Reading Measures.* The Woodcock Reading Mastery Tests-Revised (WRMT-R; Woodcock, 1987) is a non-speeded measure that can be used to assess reading achievement in children. The Word Identification and Word Attack subtests from the WRMT-R were administered. The Word Identification task requires children to name individually presented words (e.g., “red”) of increasing difficulty whereas the Word Attack task requires children to name individually presented pronounceable nonwords (e.g., “fip”) of increasing difficulty. Split-half reliability is reported to be very high (i.e., Word ID = .97; Word Attack = .89) (Woodcock, 1998). Validity is reflected by the gradual increase in scores across the age range of the battery. As well, the WRMT-R is significantly correlated with composite scores
from the Woodcock Johnson Achievement and Cognitive Abilities battery (i.e., Letter-Word Identification, Total Reading), thus demonstrating concurrent validity (Woodcock, 1998).

*Speeded Reading Measures.* The Sight Word Efficiency and Phonemic Decoding Efficiency subtests from the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999) as well as the Nonsense Word Fluency task from the DIBELS (Kaminski & Good, 1996) were administered to assess speeded reading ability. The Sight Word Efficiency task requires children to read as many real printed words (e.g., “was”) as possible within a 45 second time limit whereas the Phonemic Decoding Efficiency task requires children to read as many pronounceable printed nonwords (e.g., “sline”) as possible within a separate 45 second time period. Torgesen et al. (1999) report strong content, criterion, and construct validity for the TOWRE. In addition, test-retest reliability coefficients are high (i.e., .83 to .96) and alternate forms reliability coefficients exceed .90 (Torgesen et al., 1999). The Nonsense Word Fluency task is a standardized test that assesses letter-sound correspondence and the ability to blend letter sounds into words (Kaminski & Good, 1996). Administration of the task involves showing each participant a list of randomly ordered vowel-consonant and consonant-vowel-consonant nonsense words (e.g., tof, ac, veg) and asking that each word be read or that each individual letter sound be produced. For example, if the stimulus word is “fap”, a participant could respond, “/f/ /a/ /p/” or say the word “/fap/” to obtain a total of three correct letter-sounds. Each participant is allowed one minute to produce as many letter sounds or read as many words as he or she can. The one-month, alternate-form reliability is .83 for first graders (Good et al., 2001) The criterion-related validity of this measure with the Woodcock-Johnson Psycho-Educational Battery-Revised Readiness Cluster score is .36 in January and .59 in February of first grade (Good et al., 2001). Predictive validity is .66 with Woodcock-Johnson Psycho-Educational Battery (Woodcock & Johnson, 1989) total reading cluster score (Good et al., 2001). Although intended for use with children in Kindergarten through the beginning of second grade, the Nonsense Word Fluency task was lengthened and then piloted with older children by this author, with the goal of ensuring that no participant reached ceiling. That is, during piloting and actual testing, an alternate form of the Nonsense Word Fluency task was readily available and administered in addition to an original version of the task for any child who was capable of completing the original version in less than one minute. Thirty-five children required the alternate form in addition to the original Nonsense Word Fluency measure.
Inattention Measures

Conners’ Continuous Performance Test II (CPT-II; Conners, 2000). The CPT II consists of a 14-minute computer program that requires children to press the space bar or click the mouse button every time they see a letter, except the target letter “X”. In this study, children were instructed to click the mouse button. Rather than responding only to target stimuli, children were required to respond continuously and needed to inhibit responding when they saw the target stimulus (i.e., “X”). Interstimulus intervals within the CPT II are variable (i.e., 1, 2, and 4 seconds). Whereas the test consists of six blocks, with three sub-blocks, each containing 20 trials (letter presentations), the program runs for a continuous 14 minutes and appears seamless. The CPT II yields a number of scores including omission errors, commission errors, and a variety of reaction time and variability scores. The variables of greatest interest in the current study were omission errors and the hit reaction time block change index. Omission errors are defined as the number of targets to which an individual does not respond and are assumed to reflect inattention (e.g., Corkum & Siegel, 1993; Epstein, Conners, Sitarenios & Erhardt, 1998; Halperin, Sharma, Greenblatt, & Schwartz, 1991; Nichols & Waschbusch, 2004). Hit reaction time is defined as the average response time for all target responses over all six time blocks. The hit reaction time block change measure, calculated by computing the slope of change in reaction times over the six time blocks, reflects a decrease in vigilance across the task if there is one (Conners, 2000) and thus appears to be tapping “sustained attention.”

Conners (2000) reviewed the psychometric properties of the CPT II based upon both his preliminary research with the instrument as well as data collection across multiple sites. Split-half reliability of the CPT-II was assessed on 520 cases and found to be high (e.g., omissions = .94). Whereas test-retest correlations have proven to be highly variable (e.g., omissions = .84; hit reaction time block change = .28), a small sample size (i.e., 23 participants) including two “highly inconsistent” participants reduces this concern somewhat. It is interesting to note, as well, that despite poor reliability, the hit reaction time block change measure is capable of differentiating ADHD versus non-clinical groups. Omission errors are similarly capable of distinguishing between ADHD and non-clinical groups (Conners, 2000). Results from studies examining the predictive utility of the CPT II using non-normative samples show that the CPT II is capable of differentiating children and adults who have been diagnosed with ADHD versus controls (e.g., Barry, Klinger, Lyman, Bush, & Hawkins, 2001; Epstein et al., 1998; Perugini,
Discriminative validity of the CPT II appears to be poor, however. In a study by McGee et al. (2000), CPT II performance was found to be more strongly correlated with children’s phonological awareness relative to ADHD status, whereas in a study by Walker et al. (2000), the CPT II was unable to discriminate between adults with ADHD and those with other psychiatric conditions. It seems reasonable, however, that sustained attention would be related to both phonological awareness in children and adult psychiatric disorders, thus the poor discriminative validity of the CPT II is of limited concern within the present study.

Despite some limitations, the CPT II has adequate psychometric properties and appears to be the best standardized measure of continuous performance relative to the few other options. Concerns related to the low reliability of the hit reaction time block change variable were reduced in that this variable was utilized in conjunction with the omission errors variable within analyses. In addition, analyses were designed to show the relative contribution of each to prediction.

**ADHD Rating Scale-IV: Home Version** (DuPaul, Power, Anastopoulos, & Reid, 1998). The ADHD Rating Scale-IV is a norm-referenced checklist that measures the symptoms of attention deficit/hyperactivity disorder (ADHD) based on diagnostic criteria from the DSM-IV (American Psychiatric Association, 1994). Parents are asked to reflect on their child’s past six months of behavior and then use a 4-point Likert scale (0 = never or rarely, 1 = sometimes, 2 = often, 3 = very often) to rate each of the 18 items. Items are summed and contribute to an Inattention subscale, Hyperactivity-Impulsivity subscale, and Total Scale score. The Inattention items correspond to the DSM-IV-TR description of inattention: fails to give close attention to details, makes careless mistakes, has difficulty sustaining attention, loses things necessary for tasks or activities, often easily distracted by extraneous stimuli, and often forgetful in daily activities (American Psychiatric Association, 2000). The Hyperactivity-Impulsivity items correspond to the DSM-IV-TR description of hyperactivity: leaves seat often in the classroom or in other situations in which remaining seated is expected, runs about or climbs excessively, has difficulty playing or engaging in leisure activities quietly, and often “on the go” or “driven by a motor” (American Psychiatric Association, 2000). The ADHD Rating Scale-IV: Home Version demonstrates adequate reliability and validity. Coefficient alphas (i.e., reflecting internal consistency) of the Inattention scale, Hyperactivity/Impulsivity scale and Total scale are .86, .88,
and .92, respectively. Test-retest reliabilities across a four-week period are .78 for Inattention, .86 for Hyperactivity/Impulsivity, and .85 for Total Score (DuPaul et al., 1998). Criterion-referenced validity was addressed by DuPaul et al. (1998) by examining the relationship between the ADHD Rating Scale-IV and the Conners Parent Rating Scale-48 (CPRS-48). Significantly stronger relationships were evidenced between the Hyperactivity/Impulsivity subscale of the ADHD Rating Scale-IV: Home Version and the CPRS-48 Conduct Problems, Hyperactivity-Impulsivity, and Hyperactivity index scores, respectively, as compared to relationships between the Inattention subscale and these three indices. In contrast, the ADHD Rating Scale-IV Inattention subscale was more strongly correlated with the Learning Problems subscale of the CPRS-48 than was the Hyperactivity/Impulsivity subscale from the ADHD Rating Scale-IV. Comparisons made utilizing the parent-rated Child Behavior Checklist (CBCL; Achenbach, 1991a, 1991b, 1991c) demonstrate that CBCL parent ratings of Inattention were significantly higher for children in the predominately ADHD Rating Scale-IV Inattentive and Combined subtype groups versus clinical controls. The parent-rated ADHD Rating Scale-IV Inattention subscale was relatively weak in terms of its ability to predict classroom behavioral and academic measures, especially compared to teacher ratings of the same. Overall, however, the ADHD Rating Scale-IV: Home Version has adequate psychometric properties and represents a suitable measure for contrasting with children’s performance on the presumably more sensitive CPT II.

**Verbal Intelligence**

*Stanford-Binet Vocabulary.* Vocabulary is consistently the highest subtest associated with “g,” or general verbal ability (Sattler, 1988). To control for verbal IQ within analyses, the Vocabulary subtest from the Stanford-Binet Intelligence Scale (4th Ed., Thorndike, Hagen & Sattler, 1986) was administered. Children were asked the meaning of words (or shown pictures, for very early items) until they reached ceiling, as outlined by the standard test administration procedures. The Vocabulary subtest has strong internal consistency (i.e., $r = .87$) loads highest on $g$ (relative to the other Stanford-Binet subtests), and correlates highly (i.e., $r = .81$) with the Composite Score (Thorndike et al., 1986).

*Letter Identification*

Because study participants were seven years of age or older, it was anticipated that all would be capable of naming the 26 letters of the alphabet. To be certain of this, each child was
administered a Letter Identification task that required participants to name each uppercase letter of the alphabet, presented in a random order on an individual card. This Letter Identification task was administered prior to the administration of the remaining language-related tasks. Although recognition was perfect across participants, had any child made more than one error, he or she would have been excluded from the study due to the potential impact of this type of weakness on RAN-letters and CPT performance. Related to this, participants committing more than one error may have been evidencing a significant cognitive delay or have been learning English as a second language.

Procedures

Data collection began after consent forms had been completed and returned. Each child whose parent had given consent was required to provide their own written assent (see Appendix A) at the beginning of each of the two testing sessions. In addition to providing a brief description of the study, the purpose of the child assent was to communicate to each child that their parent(s) had given permission for them to participate and to explain that they had the option to choose for themselves whether they wished to participate and also had the option to stop at any time that they wished without penalty.

Test Administration. Children were tested individually in a quite environment outside of the classroom across two sessions which each lasted approximately 20 to 25 minutes. Presentation of sessions was randomly counterbalanced across subjects, with most subjects receiving both testing sessions within the same week. The order of test administration for one session was Letter Knowledge, four RAN tasks (i.e., letters, digits, colors and objects) presented in random order, Elision, Blending Words, Phoneme Segmentation Fluency, Nonsense Word Fluency, Word Identification, Word Attack, Sight Word Efficiency, and Phonemic Decoding Efficiency. During an alternate test session, vocabulary knowledge and CPT II performance were assessed. In year one of testing, all measures were administered by this author. In year two of testing, a trained undergraduate assistant administered the CPT II to approximately 30 participants; the Vocabulary subtest was administered within two days of this by the present author. The CPT II was administered via laptop computer, as outlined above. After demonstrating his or her understanding of the CPT II during a short practice test, each participant began the actual 14-minute test.
If a participant indicated a desire to quit during any task, he or she was thanked and then escorted from the room. Only one child chose to quit language testing; this child appeared anxious and was not asked back. Six children chose to discontinue testing with the CPT II; many of these children made comments suggesting that they were experiencing frustration related to the length of the CPT II (e.g., “Can I stop now?”; “I’m tired of doing this”). Given the specificity of these comments as well as the eagerness of almost all children to join the examiner for a “second turn,” children administered the CPT II during the first testing session were subsequently asked whether they would like to leave the classroom (i.e., for a “second turn”) to engage in an assessment with language measures. All children readily agreed.

Finally, to ensure that participants ended each session with a positive experience, very brief word find activities were administered at the end of each of the two testing sessions. Children were asked to circle the first two words that they found during these tasks and were praised for their speed and ability.

Behavioral Questionnaires. Once test administration was complete for all participants within a particular school (i.e., within a maximum two week period), personalized envelopes were sent home with children. Each envelope contained an ADHD Rating Scale-IV: Home Version and an explanatory letter. Parents were provided a one-week deadline for the return of questionnaires. The majority of questionnaires were returned within one week. In several cases, however, reminder notices were sent home with new questionnaires. Of the 94 questionnaires sent home, 88 (i.e., 93.6%) were returned.
CHAPTER 3

RESULTS

Data Screening

Data were screened prior to analyses to ensure conformity with assumptions of univariate and multivariate normality. To identify univariate outliers, the criterion of the median plus or minus twice the interquartile range was used. A total of 12 univariate outliers were identified: RAN-objects (2 outliers), RAN-letters (1 outlier), RAN-digits (1 outlier), Stanford Binet vocabulary (3 outliers), omission errors (1 outlier), inattention scale (2 outliers), hyperactivity scale (2 outliers). Each outlier was replaced by a value at the upper or lower end of the corresponding acceptable range. That is, the median plus twice the interquartile range was used for high outliers; whereas the median minus twice the interquartile range was utilized for low scores.

A number of steps were taken to address missing data. With regard to the ADHD questionnaire, five children were missing one item each and two children were each missing two items. Each of these missing data points was replaced by the item median derived from the overall sample. As stated above, seven children did not return the ADHD parent rating scale and seven children who began testing with the CPT II discontinued part-way through testing; data from these participants was utilized only in analyses not involving these variables. There was concern that those who quit the CPT may have represented a biased group with poor attention. This concern was allayed, however, in that t-tests demonstrated no significant differences between CPT II completers and non-completers on any of the ADHD or language measures (i.e., all ps > .05).

Pairwise plots were examined for linearity and homoscedasticity. Three cases were identified as problematic. Analyses were completed with and without these three cases and no differences were observed so these cases were retained in the analyses. The distributions of individual variables were then evaluated for significant departures from normality by examining the skewness and kurtosis of each as recommended by Tabachnik and Fidell (1996). That is, each obtained skewness and kurtosis value was converted to a z score that was then considered in
relation to a \( p \) value of .01. Most variables were normally distributed although four variables were not (i.e., \( ps < .01 \)). The CPT II omission errors variable had significant skewness and kurtosis (skewness = 4.26; kurtosis = 24.12). A logarithmic transformation adding a constant of one prior to transformation (as discussed by Tabachnick & Fidell, 1996) was applied to the omission errors variable and this was successful in rendering the skew insignificant. Abnormal skewness and kurtosis was a problem for the Inattention Scale (skewness = .96; kurtosis = 1.75), Hyperactivity Scale (skewness = 1.04; kurtosis = 1.37), and ADHD Total Scale (skewness = 1.04; kurtosis = 1.99). This was not surprising given that the sample represented a community sample, rather than a clinical sample. The Inattention, Hyperactivity and ADHD Total variables were each subjected to a square root transformation, and these transformations were successful in addressing the significant departure from normality for each of these variables.

Finally, standardized residuals from each of the regression analyses (as discussed below) were saved and then examined for multivariate outliers. Two cases were identified as contributing toward multivariate outliers. Analyses were completed with and without these two cases and no significant differences noted in outcomes. Thus, these two cases were retained.

**Descriptive Statistics**

Descriptive statistics for all measures are provided in Table 2. Raw scores on all RAN measures (letters, digits, colors and objects), Elision, Blending Words, Word Identification, Word Attack, Sight Word Efficiency, Phonemic Decoding Efficiency, and Vocabulary were converted to standard scores using the conversion tables provided in the respective manuals. Raw scores are reported for the CPT II omission errors, commission errors, and hit reaction time block change variables, as these have a greater degree of interpretability. Moreover, conversion to \( t \)-scores produced the same results as raw data in subsequent analyses; thus, raw scores were used within analyses. Inattention, Hyperactivity, and ADHD Total scaled scores from the ADHD Rating Scale have been reported as raw scores because no option exists to convert to \( t \)-scores within the ADHD Rating Scale manual, and conversion to percentiles would have produced restricted variability for children scoring below the 80\(^{th} \) percentile.
Table 2

**Descriptive Statistics for Naming, Language, and Attention Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
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<tbody>
<tr>
<td>RAN-Letters&lt;sup&gt;a&lt;/sup&gt;</td>
<td>95</td>
<td>104.65</td>
<td>11.47</td>
<td>79 – 139</td>
<td>.14</td>
<td>.19</td>
</tr>
<tr>
<td>RAN-Digits&lt;sup&gt;a&lt;/sup&gt;</td>
<td>95</td>
<td>105.48</td>
<td>13.25</td>
<td>76 – 142</td>
<td>-.03</td>
<td>.19</td>
</tr>
<tr>
<td>RAN-Colors&lt;sup&gt;a&lt;/sup&gt;</td>
<td>95</td>
<td>103.84</td>
<td>12.15</td>
<td>73 – 128</td>
<td>-.16</td>
<td>-.28</td>
</tr>
<tr>
<td>RAN-Objects&lt;sup&gt;a&lt;/sup&gt;</td>
<td>95</td>
<td>99.97</td>
<td>12.78</td>
<td>76 – 141</td>
<td>.33</td>
<td>-.29</td>
</tr>
<tr>
<td>Elision&lt;sup&gt;b&lt;/sup&gt;</td>
<td>95</td>
<td>10.72</td>
<td>3.01</td>
<td>5 – 17</td>
<td>-.05</td>
<td>-1.0</td>
</tr>
<tr>
<td>Blending Words&lt;sup&gt;b&lt;/sup&gt;</td>
<td>95</td>
<td>9.33</td>
<td>2.05</td>
<td>5 – 14</td>
<td>.24</td>
<td>-.11</td>
</tr>
<tr>
<td>Word Identification&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94</td>
<td>110.00</td>
<td>12.02</td>
<td>73 – 138</td>
<td>-.19</td>
<td>-.03</td>
</tr>
<tr>
<td>Word Attack&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94</td>
<td>106.50</td>
<td>12.46</td>
<td>80 – 137</td>
<td>.34</td>
<td>-.41</td>
</tr>
<tr>
<td>Sight Word Efficiency&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94</td>
<td>109.40</td>
<td>13.12</td>
<td>72 – 136</td>
<td>-.59</td>
<td>.13</td>
</tr>
<tr>
<td>Phonemic Decoding&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94</td>
<td>105.35</td>
<td>15.32</td>
<td>58 – 137</td>
<td>-.16</td>
<td>-.06</td>
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<tr>
<td>Phoneme Segmentation&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94</td>
<td>100.00</td>
<td>14.92</td>
<td>66.51 – 132.64</td>
<td>-.08</td>
<td>-.72</td>
</tr>
<tr>
<td>Nonsense Word Fluency&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94</td>
<td>100.00</td>
<td>14.92</td>
<td>63.67 – 131.42</td>
<td>.07</td>
<td>-.73</td>
</tr>
<tr>
<td>Stanford Binet Vocabulary&lt;sup&gt;c&lt;/sup&gt;</td>
<td>94</td>
<td>55.79</td>
<td>7.23</td>
<td>34 – 75</td>
<td>.03</td>
<td>.65</td>
</tr>
<tr>
<td>CPT II omission errors (inattention)</td>
<td>86</td>
<td>13.38</td>
<td>17.49</td>
<td>0 – 129</td>
<td>4.26</td>
<td>24.12</td>
</tr>
<tr>
<td>CPT II commission errors</td>
<td>86</td>
<td>24.05</td>
<td>6.81</td>
<td>6-35</td>
<td>-.67</td>
<td>-.10</td>
</tr>
<tr>
<td>CPT II hit reaction time BC (inattention)</td>
<td>86</td>
<td>.01</td>
<td>.02</td>
<td>-.04 -.08</td>
<td>.30</td>
<td>.332</td>
</tr>
<tr>
<td>Parent-rated Inattention</td>
<td>87</td>
<td>5.76</td>
<td>3.98</td>
<td>0 – 21</td>
<td>.96</td>
<td>1.75</td>
</tr>
<tr>
<td>Parent-rated Hyperactivity-Impulsivity</td>
<td>87</td>
<td>4.43</td>
<td>3.72</td>
<td>0 – 18</td>
<td>1.04</td>
<td>1.37</td>
</tr>
<tr>
<td>Parent-rated ADHD</td>
<td>87</td>
<td>10.18</td>
<td>7.12</td>
<td>0 - 39</td>
<td>1.04</td>
<td>1.99</td>
</tr>
</tbody>
</table>

*Note.* CPT II = Continuous Performance Test II; BC = Block Change; <sup>a</sup>These values reflect standard scores with a mean of 100 and SD of 15. <sup>b</sup>These values reflect standard scores with a mean of 10 and standard deviation of 3. <sup>c</sup>These values reflect standard scores with a mean of 50 and SD of 8.
An examination of the mean standard or mean raw scores for each measure (see Table 2) revealed that participants in this study performed significantly better than normative groups on most naming and language measures. That is, confidence intervals (i.e., 95%) were established for the study sample on each naming and language measure and normative group means were observed to fall outside of these established intervals on RAN-letters, RAN-digits, RAN-objects, RAN-colors, Elision, Word Identification, Word Attack, Sight Word Efficiency, Phonemic Decoding, and Stanford Binet vocabulary. This raises concern about the ability to generalize based upon the results of this study, as will be discussed later. The average performance of children in the normative group on Blending Words (i.e., 10.00) fell above this sample’s confidence interval (i.e., 8.91 to 9.74) on this measure thus indicating that children in this study scored much lower on the Blending Words measure as compared to children in the standardization sample. This was of limited concern, however, as the Blending Words and Elision subtests were averaged to form a phonological awareness composite score with a mean value equivalent to that of the standardization sample. This phonological awareness composite score was utilized within regression analyses.

It was not possible to compare children’s performance on the DIBELS Nonsense Word Fluency and Phoneme Segmentation Fluency measures to the performance of normative groups because these standardized tasks were modified for use with older children in the current study. Thus, norms only existed for younger but not older children. Distributions were normal for both the Nonsense Word Fluency and Phoneme Segmentation Fluency tasks, however, and there were no obvious floor or ceiling effects. Scores on the ADHD-IV Rating Scale were within the expected range (i.e., equivalent to those in the standardization sample). It was difficult to determine if children in this study obtained comparable scores to normative groups on the Continuous Performance Task, as normative data was not provided within the CPT II manual for non-clinical samples. The task’s publisher was contacted, however, and it was determined that the current sample performed within the normal range on the omission errors and hit reaction time block change indices of the CPT II.

Composite variables were created to reduce the number of required analyses. Pairs of conceptually similar variables were combined by taking the two tasks making up the pair and weighting them equally. The Elision and Blending Words subtests from the CTOPP contributed to a Phonological Awareness Composite Score, as discussed by Wagner et al. (1999). A Speeded
Reading Composite (Sight Word Efficiency and Phonemic Decoding Efficiency) and a Non-Speeded Reading Composite (Word Identification and Word Attack) were also formed. Finally, given the strong correlation between the RAN-letters and RAN-digits tasks (i.e., $r = .71$) these two variables were averaged to form a RAN-letters/digits composite. A RAN-colors/objects composite was created by averaging the RAN-colors and RAN-objects tasks ($r = .57$).

**Rapid Naming Ability in the Prediction of Reading**

The first hypothesis was that performance on RAN-letters and RAN-digits would each significantly predict reading outcomes whereas performance on RAN-colors and RAN-objects would not predict reading. One issue that needed to be considered when assessing the relation between RAN and reading was that RAN was a speeded independent variable. It was therefore necessary to consider the impact of having a speeded independent variable (i.e., RAN) contribute significant variance to a speeded dependent reading measure, and hence spuriously inflate the predictive ability of RAN, simply because both variables were speeded. Thus, hierarchical regression analyses to address the first hypothesis were conducted using both speeded and non-speeded reading outcome variables in addition to the RAN predictor variables. Although analyses were planned to also include both speeded and non-speeded measures of phonological awareness, the speeded Phoneme Segmentation Fluency measure proved to be invalid and thus could not be utilized. That is, Phoneme Segmentation Fluency was significantly negatively correlated with almost every reading measure in this study (see Table 3). Analyses therefore proceeded utilizing the non-speeded Phonological Awareness Composite Score (Elision and Blending Words). The purpose of these four analyses was to determine if RAN was consistently predictive of reading regardless of the method utilized to assess phonological awareness and reading (i.e., speeded versus non-speeded measures). The reading outcome variables were the Speeded Reading Composite (Sight Word Efficiency and Phonemic Decoding Efficiency) and the Non-Speeded Reading Composite (Word ID and Word Attack). The model utilized for all hierarchical regressions included three blocks of variables. In the first block, the control variables of Age and Verbal IQ (i.e., Stanford Binet Vocabulary) were entered. In the second block, the Phonological Awareness Composite was entered. In the final block, the RAN-letters/digits composite, or RAN-colors/objects composite was entered.

In the first analysis (see Table 4), RAN-letters/digits uniquely accounted for 17% of the variance in the Speeded Reading Composite after Age, Verbal IQ, and the Phonological
Awareness Composite Score were entered in the equation, $F_{inc}(1, 89) = 28.6, p < .01$. The second analysis (see Table 5) demonstrated that RAN-colors/objects uniquely accounted for 4.7% of the variance in the Speeded Reading Composite after Age, Verbal IQ, and the Phonological Awareness Composite Score were entered in the equation, $F_{inc}(1, 89) = 6.36, p < .05$. An examination of the standardized beta coefficients demonstrated that the RAN-letters/digits composite was a significant predictor of speeded reading at the $p < .01$ level of statistical significance, whereas the RAN-colors/objects composite was a significant predictor of speeded reading at the $p < .05$ level of statistical significance. Subsequent analyses demonstrated that RAN-letters/digits uniquely accounted for 8% of the variance in the Non-Speeded Reading Composite after Age, Verbal IQ, and the Phonological Awareness Composite Score entered the equation, $F_{inc}(1, 89) = 14.8, p < .01$ (see Table 6). In contrast, the contribution of RAN-colors/objects to the Non-Speeded Reading Composite was non-significant, after controlling for the impact of Age, Verbal IQ, and the Phonological Composite Score $F_{inc}(1, 89) = 2.77, p > .10$ (see Table 7).

To summarize, it was hypothesized that RAN-letters/digits would be a significant predictor of reading ability, whereas RAN-colors/objects was not anticipated to be a significant predictor of reading. Consistent with prediction, results from analyses involving speeded measures as well as analyses utilizing non-speeded measures demonstrated that the RAN-letters/digits composite was a significant predictor of reading, even after controlling for phonological ability. The RAN-colors/objects composite was also a significant predictor of speeded reading, but it was not predictive of non-speeded reading. These findings considered together suggest that it was most likely the speeded aspect of the RAN-colors/objects composite that contributed significant variance to the Speeded Reading Composite rather than specific non-speeded constructs which were being tapped by the RAN-colors and RAN-objects naming tasks.
Table 3
Partial Correlations (controlling for Age and Verbal IQ) between RAN Measures and Language Measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>1. RAN-letters</td>
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<tr>
<td>2. RAN-digits</td>
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<td>3. RAN-colors</td>
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<tr>
<td>4. RAN-objects</td>
<td>.52**</td>
<td>.49**</td>
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<tr>
<td>5. Elision</td>
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<td>.23*</td>
<td>.20</td>
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<td></td>
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</tr>
<tr>
<td>6. Blending Words</td>
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<td>-.04</td>
<td>.03</td>
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</tr>
<tr>
<td>7. Phoneme Segmentation Fluency</td>
<td>-.08</td>
<td>-.15</td>
<td>-.04</td>
<td>-.02</td>
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<td>.16</td>
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<tr>
<td>8. Nonsense Word Fluency</td>
<td>.58**</td>
<td>.52**</td>
<td>.33**</td>
<td>.25*</td>
<td>.41**</td>
<td>.15</td>
<td>-.24*</td>
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<tr>
<td>9. Word Identification</td>
<td>.43**</td>
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<td>.16</td>
<td>.14</td>
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<td>.35**</td>
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<tr>
<td>10. Word Attack</td>
<td>.39**</td>
<td>.32**</td>
<td>.24*</td>
<td>.18*</td>
<td>.48**</td>
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<td>-.28**</td>
<td>.64**</td>
<td>.76**</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>11. Sight Word Efficiency</td>
<td>.49**</td>
<td>.44**</td>
<td>.25*</td>
<td>.30**</td>
<td>.26*</td>
<td>.19*</td>
<td>-.28**</td>
<td>.76**</td>
<td>.72**</td>
<td>.55**</td>
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</tr>
<tr>
<td>12. Phonemic Decoding Efficiency</td>
<td>.47**</td>
<td>.44**</td>
<td>.27*</td>
<td>.15</td>
<td>.38**</td>
<td>.27*</td>
<td>-.25*</td>
<td>.79**</td>
<td>.78**</td>
<td>.78**</td>
<td>.75**</td>
</tr>
</tbody>
</table>

Note. N = 94. *p < .05, **p < .01
**Table 4**

*Summary of Hierarchical Regression Analysis including RAN-letters/ digits in the prediction of Speeded Reading (Sight Word Efficiency and Phonemic Decoding Efficiency)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model $R^2$</th>
<th>Change in $R^2$</th>
<th>$F_{inc}$</th>
<th>$\beta$</th>
<th>$sr^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>.18</td>
<td>.18</td>
<td>10.17**</td>
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</tr>
<tr>
<td>Verbal IQ</td>
<td></td>
<td></td>
<td></td>
<td>.33**</td>
<td>.30**</td>
</tr>
<tr>
<td>Step 2</td>
<td>.30</td>
<td>.12</td>
<td>15.35**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonological Awareness$^a$</td>
<td></td>
<td></td>
<td></td>
<td>.28**</td>
<td>.25**</td>
</tr>
<tr>
<td>Step 3</td>
<td>.47</td>
<td>.17</td>
<td>28.61**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAN-letters/digits</td>
<td></td>
<td></td>
<td></td>
<td>.42**</td>
<td>.41**</td>
</tr>
</tbody>
</table>

*Note. N = 94.*

$^a$Phonological Awareness comprised of (Non-speeded) Elision and Blending Words tasks.

* $p < .05$, ** $p < .01$

**Table 5**

*Summary of Hierarchical Regression Analysis including RAN-objects/colors in the prediction of Speeded Reading (Sight Word Efficiency and Phonemic Decoding Efficiency)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model $R^2$</th>
<th>Change in $R^2$</th>
<th>$F_{inc}$</th>
<th>$\beta$</th>
<th>$sr^2$</th>
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</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>.18</td>
<td>.18</td>
<td>10.17**</td>
<td></td>
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</tr>
<tr>
<td>Age</td>
<td>.13</td>
<td>.13</td>
<td></td>
<td>.13</td>
<td></td>
</tr>
<tr>
<td>Verbal IQ</td>
<td></td>
<td></td>
<td></td>
<td>.29**</td>
<td>.27**</td>
</tr>
<tr>
<td>Step 2</td>
<td>.30</td>
<td>.12</td>
<td>15.35**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonological Awareness$^a$</td>
<td></td>
<td></td>
<td></td>
<td>.34**</td>
<td>.31**</td>
</tr>
<tr>
<td>Step 3</td>
<td>.35</td>
<td>.05</td>
<td>6.36*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAN-objects/colors</td>
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<td></td>
<td></td>
<td>.22*</td>
<td>.22*</td>
</tr>
</tbody>
</table>

*Note. N = 94.*

$^a$Phonological Awareness comprised of (Non-speeded) Elision and Blending Words tasks.

* $p < .05$, ** $p < .01
### Table 6

*Summary of Hierarchical Regression Analysis Including RAN-letters/digits in the Prediction of Non-Speeded Reading (Word Identification and Word Attack)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model $R^2$</th>
<th>Change in $R^2$</th>
<th>$F_{inc}$</th>
<th>$\beta$</th>
<th>$sr^2$</th>
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</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>.23</td>
<td>.23</td>
<td>13.72**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td>-.10</td>
<td>-.10</td>
<td></td>
</tr>
<tr>
<td>Verbal IQ</td>
<td></td>
<td></td>
<td>.27**</td>
<td>.25**</td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td>.45</td>
<td>.22</td>
<td>36.01**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonological Awareness$^a$</td>
<td></td>
<td></td>
<td>.44**</td>
<td>.40**</td>
<td></td>
</tr>
<tr>
<td>Step 3</td>
<td>.53</td>
<td>.08</td>
<td>14.81**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAN-letters/digits</td>
<td></td>
<td></td>
<td>.29**</td>
<td>.28**</td>
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</tr>
</tbody>
</table>

*Note.* $N = 94$.

$^a$Phonological Awareness comprised of (Non-speeded) Elision and Blending Words tasks.

* $p < .05$, ** $p < .01$

### Table 7

*Summary of Hierarchical Regression Analysis Including RAN-objects/colors in the Prediction of Non-Speeded Reading (Word Identification and Word Attack)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model $R^2$</th>
<th>Change in $R^2$</th>
<th>$F_{inc}$</th>
<th>$\beta$</th>
<th>$sr^2$</th>
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<tbody>
<tr>
<td>Step 1</td>
<td>.23</td>
<td>.23</td>
<td>13.72**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td>-.11</td>
<td>-.11</td>
<td></td>
</tr>
<tr>
<td>Verbal IQ</td>
<td></td>
<td></td>
<td>.25**</td>
<td>.23**</td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td>.45</td>
<td>.22</td>
<td>36.01**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonological Awareness$^a$</td>
<td></td>
<td></td>
<td>.49**</td>
<td>.45**</td>
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<tr>
<td>Step 3</td>
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<td>.02</td>
<td>2.77</td>
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<tr>
<td>RAN-objects/colors</td>
<td></td>
<td></td>
<td>.13</td>
<td>.13</td>
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</tr>
</tbody>
</table>

*Note.* $N = 94$.

$^a$Phonological Awareness comprised of (Non-speeded) Elision and Blending Words tasks.

* $p < .05$, ** $p < .01*
The second hypothesis of the study was that inattention would predict naming performance whereas hyperactivity would not. More specifically, it was anticipated that inattention as assessed by the CPT II (i.e., omission errors; hit reaction time block change) as well as inattention assessed by the Inattention Scale of the ADHD-IV Rating Scale: Home Version would each significantly predict RAN performance. The Hyperactivity-Impulsivity Scale of the ADHD-IV Rating Scale: Home Version was not expected to correlate significantly with RAN performance.

To investigate whether CPT attention was predictive of naming performance, partial correlations between CPT II indices (i.e., omission errors and hit reaction time block change) and RAN measures (i.e., RAN-letters, RAN-digits, RAN-colors, and RAN-objects) were computed (see Table 8). Age and Verbal IQ were controlled for, to ensure that any potential results did not reflect differences in age and/or verbal abilities across the sample. Results of these analyses revealed that there were no significant relations between CPT II omission errors and any of the RAN tasks (i.e., RAN-letters, RAN-digits, RAN-colors, and RAN-objects). There were no significant correlations between the CPT II hit reaction time block change variable and any RAN measure. Thus, the CPT II indices of omission errors and hit reaction time block change, respectively, were not significantly predictive of RAN performance, contrary to expectation. Simple correlations were examined as well to determine if the results would differ if Verbal IQ and Age were not controlled for. None of the simple correlations between the CPT II indices (i.e., omission errors and hit reaction time block change) and RAN measures were significant (i.e., all \( p < .05 \)).

To determine whether parent-rated inattention or hyperactivity were significantly predictive of RAN, partial correlations controlling for age and verbal IQ between the Inattention and Hyperactivity-Impulsivity scales, respectively, of the ADHD Rating Scale-IV: Home Version, and RAN measures were computed (see Table 8). Results demonstrated that neither parent-rated inattention nor parent-rated hyperactivity-impulsivity correlated significantly with any of the RAN measures. Analyses employing simple correlations yielded the same results. Thus, the results of this study did not support the hypothesis that inattention significantly predicts performance on RAN-letters, RAN-digits, RAN-colors, and RAN-objects. Consistent
with expectation, the Hyperactivity-Impulsivity scale was not significantly correlated with RAN-letters, RAN-digits, RAN-colors, or RAN-objects.

**Inattention and Reading**

The relation between inattention and reading was also examined to determine how CPT omission errors and parent ratings of inattention, respectively, related to speeded versus non-speeded reading outcomes. Correlations were examined between CPT omission errors, the CPT hit reaction time block change index, the Inattention scale of the ADHD Rating Scale-IV, and speeded and non-speeded reading composites (see Table 9). Results of this analysis revealed that CPT omission errors were not significantly associated with speeded reading (i.e., \( p > .05 \)); however, the relation between omission errors and non-speeded reading was significant (\( p = .05 \)). The CPT hit reaction time block change index was unrelated to reading outcomes (i.e., \( ps > .05 \)). Parent-rated inattention was not associated with speeded reading (i.e., \( p > .05 \)). Similarly, parent-rated inattention was not associated with non-speeded reading (i.e., \( p > .05 \)).

**The relation between CPT II indices and the ADHD Rating Scale-IV**

To determine how CPT II attention indices (i.e., omission errors; hit reaction time block change) related to parent-rated inattention versus parent-rated hyperactivity versus overall ADHD, partial correlations controlling for age and verbal IQ between CPT II indices (omission errors and hit reaction time block change, respectively) and the ADHD Rating Scale-IV: Home Version (Inattention, Hyperactivity-Impulsivity, and Total Scales) were computed (see Table 8). Results demonstrated that CPT II omission errors correlated significantly with both the parent-rated Inattention (i.e., \( r = .25; p < .05 \)) and parent-rated ADHD Total Scales (i.e., \( r = .25; p < .05 \)) but CPT II omission errors were not significantly associated with the parent-rated Hyperactivity-Impulsivity Scale (i.e., \( r = .15; p > .05 \)). The CPT hit reaction time block change measure was not significantly correlated with any of the ADHD-IV Scales (i.e., all \( ps > .05 \)).
### Table 8

*Partial Correlations (controlling for Age and Verbal IQ) between RAN measures, CPT II measures, ADHD Rating Scale, and Phonological Awareness*

<table>
<thead>
<tr>
<th>Predictors</th>
<th>1</th>
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<th>4</th>
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<th>7</th>
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<th>10</th>
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<tbody>
<tr>
<td>1. RAN-Letters</td>
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<tr>
<td>2. RAN-Digits</td>
<td>.71**</td>
<td>---</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>3. RAN-colors</td>
<td>.61**</td>
<td>.57**</td>
<td>---</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. RAN-objects</td>
<td>.53**</td>
<td>.46**</td>
<td>.56**</td>
<td>---</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5. Phonological Awareness&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.26*</td>
<td>.16</td>
<td>.14</td>
<td>.10</td>
<td>---</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>6. CPT II-omissions (inattention)</td>
<td>-.19</td>
<td>.02</td>
<td>-.05</td>
<td>-.13</td>
<td>-.36**</td>
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<tr>
<td>7. CPT II-commissions (impulsivity)</td>
<td>.04</td>
<td>.15</td>
<td>.09</td>
<td>-.06</td>
<td>-.04</td>
<td>.31**</td>
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</tr>
<tr>
<td>8. CPT II-hit reaction time BC (inattention)</td>
<td>.04</td>
<td>-.02</td>
<td>.04</td>
<td>-.02</td>
<td>.01</td>
<td>-.01</td>
<td>-.12</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9. Parent-rated Inattention</td>
<td>-.03</td>
<td>-.10</td>
<td>-.13</td>
<td>-.08</td>
<td>-.07</td>
<td>.25*</td>
<td>.11</td>
<td>-.07</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>10. Parent-rated Hyperactivity-Impulsivity</td>
<td>.15</td>
<td>.00</td>
<td>-.07</td>
<td>-.05</td>
<td>-.01</td>
<td>.15</td>
<td>-.03</td>
<td>-.03</td>
<td>.63**</td>
<td>---</td>
</tr>
<tr>
<td>11. Parent-rated Total ADHD</td>
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<td>-.04</td>
<td>-.11</td>
<td>-.08</td>
<td>-.07</td>
<td>.25*</td>
<td>.07</td>
<td>-.07</td>
<td>.91**</td>
<td>.88**</td>
</tr>
</tbody>
</table>

*Note. N = 77.*

<sup>a</sup>Phonological Awareness comprised of (Non-speeded) Elision and Blending Words tasks

*<sup>p</sup> < .05, **<sup>p</sup> < .01
Table 9

*Partial Correlations (controlling for Age and Verbal IQ) between Inattention and Reading*

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
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<tbody>
<tr>
<td>1. CPT omissions (Inattention)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2. CPT commissions (Hyperactivity)</td>
<td>.31**</td>
<td>--</td>
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<td></td>
</tr>
<tr>
<td>3. CPT hit reaction time BC (Inattention)</td>
<td>-.01</td>
<td>-.12</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Parent-rated Inattention</td>
<td>.25*</td>
<td>.11</td>
<td>-.07</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Parent-rated Hyperactivity/Impulsivity</td>
<td>.15</td>
<td>-.03</td>
<td>-.03</td>
<td>.63**</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>6. Non-speeded reading^b</td>
<td>-.22</td>
<td>.03</td>
<td>-.08</td>
<td>-.11</td>
<td>.06</td>
<td>--</td>
</tr>
<tr>
<td>7. Speeded reading^a</td>
<td>-.13</td>
<td>.14</td>
<td>-.08</td>
<td>-.03</td>
<td>.07</td>
<td>.81**</td>
</tr>
</tbody>
</table>

*Note. N = 77.*  
BC = block change; ^aSpeeded reading comprised of sight word efficiency and phonemic decoding efficiency measures; ^bNon-speeded reading comprised of word attack and word identification measures.  
*p < .05, **p < .01

*Phonological Awareness in the prediction of Rapid Automatized Naming (RAN)*

For the third hypothesis it was anticipated that phonological awareness would significantly predict performance on RAN-letters and RAN-digits but not predict performance on RAN-objects and RAN-colors. Partial correlations, controlling for age and verbal IQ were examined between the Phonological Awareness Composite (i.e., Blending Words and Elision) and RAN-letters, RAN-digits, RAN-objects, and RAN-colors (see Table 8). Results showed that the Phonological Awareness Composite was significantly predictive of RAN-letters (i.e., p < .05) but not RAN-digits, RAN-objects, or RAN-colors (all ps > .05).

*Discriminant Validity of the CPT II*

The fourth hypothesis, that CPT II scores would be more predictive of RAN performance than of performance on phonological awareness measures, was included to address the issue of discriminant validity. That is, had the CPT II omission errors and hit reaction time block change indices been significantly predictive of naming performance (i.e., hypothesis two), it would have been important to show that the CPT II was specifically predictive of naming and not simply predictive of a multitude of measures including naming. Given the finding that CPT II indices
were not significantly predictive of RAN, it was somewhat irrelevant to follow up regarding the discriminant validity of the CPT II. The proposed analyses were conducted anyhow to examine if CPT II scores were more predictive of phonological awareness than they were of RAN scores.

To address the fourth hypothesis, partial correlations between the CPT II omission errors, commission errors and hit reaction time block change indices, the four RAN measures (RAN-letters, RAN-digits, RAN-colors, and RAN-objects), and the Phonological Awareness Composite were examined (see Table 8). Contrary to prediction, the correlation between CPT II omission errors and the Phonological Awareness Composite Score was statistically significant \( r = -.36; p < .01 \). In contrast, none of the RAN tasks were significantly correlated with CPT II omission errors. Whereas CPT II commission errors were significantly correlated with CPT II omission errors, CPT commission errors were not significantly associated with any other variable. The CPT II hit reaction time block change index did not correlate significantly with any of the RAN measures or with the Phonological Awareness Composite. Thus, no support was demonstrated for the discriminant validity of the CPT II in the prediction of inattention.

**Length of RAN in the Prediction of Reading**

It was hypothesized that the naming of 40 or 50 items from the RAN letters, digits, objects, and colors tasks, respectively, would correlate more strongly with both the omission errors and hit reaction time block change indices from the CPT II as well as with parent-rated inattention than the naming of 10 or 20 RAN items. Furthermore, it was anticipated that the naming of 40 or 50 items from both the RAN-letters and RAN-digits tasks, respectively, would be more predictive of reading than the naming of 10 or 20 items due to the hypothesized greater demands on attention associated with naming relatively more items.

To determine whether length of RAN was associated with inattention, intercorrelations were examined (see Tables 10-13) between successive variants of each of the four RAN tasks (i.e., 10, 20, 30, 40 and 50 items) and both the omission errors and hit reaction time block change indices from the CPT II as well as the Inattention scale from the ADHD Rating Scale-IV: Home Version. Comparisons were made utilizing the *Differences between Correlation Coefficients* test (Cohen, 1969). Contrary to prediction, results demonstrated that across all four types of RAN, there were no significant differences in the relation between fewer versus more RAN items and omission errors; all correlations were insignificant. Intercorrelations between fewer versus greater numbers of RAN symbols and hit reaction time block change were also examined. All
correlations were nonsignificant and extremely similar in value, and were thus not followed up with the Differences between Correlation Coefficients test (Cohen, 1969). Similarly, across all four types of RAN, there were no significant differences in the relation between fewer versus more RAN items and parent-rated inattention.

To determine whether the length of the RAN task was associated with reading, correlations were examined between successive variants of each of the four RAN tasks (i.e., number of seconds required to name 10, 20, 30, 40 and the total 50 items, respectively) and reading outcome measures and these correlations were compared using the Differences between Correlation Coefficients test (Cohen, 1969). Due to the exploratory nature of this analysis, two composite reading measures were utilized (a) Speeded Reading (Sight Word Efficiency and Phonemic Decoding Efficiency), and (b) Non-Speeded Reading (Word Identification and Word Attack). The intercorrelational analyses involving the length of time needed to name 10, 20, 30, 40, and 50 RAN stimuli, respectively, and the Speeded and Non-Speeded reading composites, respectively, are shown in Tables 10-13. Contrary to prediction, results for Non-Speeded reading revealed no significant differences in the length of time required to name shorter (i.e., 10 or 20 item) versus longer (i.e., 40 or 50 item) versions of RAN-digits and RAN-colors (i.e., ps > .10). That is, shorter and longer versions of RAN-digits and RAN-colors were equally predictive of non-speeded reading outcomes. The results from the RAN-letters task were consistent with prediction in that scores obtained after naming 10 or 20 items were significantly less related to Non-Speeded reading as compared to scores obtained after naming 40 or 50 items (p < .01). For RAN-objects, the time required to name 10 items was significantly less predictive of Non-Speeded reading as compared to the time required to name 20, 30, 40 or 50 items (ps < .05). With regard to speeded reading outcomes, there were no differences in the time needed to name fewer (i.e., 10 or 20) versus greater (i.e., 40 or 50) numbers of RAN-digits and RAN-colors (ps > 10). With regard to RAN-letters and RAN-objects, the time required to name 10 items was significantly less correlated with Speeded reading as compared to the time required to name 20, 30, 40 or 50 RAN symbols (ps < .01).

In summary, because omission errors, hit reaction time block change and parent-rated inattention were unrelated to any of the four types of RAN, it did not matter how many RAN items were named in relation to these three indices of inattention; all were nonsignificant. In
regard to the prediction of Speeded and Non-speeded reading, for both the RAN-digits and RAN-colors tasks, there was no predictive advantage in naming more than one row of RAN
Table 10

*Partial Correlations*<sup>a</sup> between number of RAN-letters named, Inattention, and Reading

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. RAN letters-10 items</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. RAN letters-20 items</td>
<td>0.84**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. RAN letters-30 items</td>
<td>0.72**</td>
<td>0.93**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. RAN letters-40 items</td>
<td>0.68**</td>
<td>0.90**</td>
<td>0.97**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. RAN letters-50 items</td>
<td>0.67**</td>
<td>0.88*</td>
<td>0.95**</td>
<td>0.97**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Speeded Reading&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.30**</td>
<td>-0.54**</td>
<td>-0.62**</td>
<td>-0.61**</td>
<td>-0.62**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Non-speeded Reading&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-0.22*</td>
<td>-0.37**</td>
<td>-0.49**</td>
<td>-0.53**</td>
<td>-0.52**</td>
<td>0.81**</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. <em>CPT II</em>-omissions (inattention)</td>
<td>0.03</td>
<td>0.01</td>
<td>0.12</td>
<td>0.16</td>
<td>0.16</td>
<td>-0.13</td>
<td>-0.22</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>9. <em>CPT II</em>-Hit Reaction Time BC (inattention)</td>
<td>-0.10</td>
<td>-0.06</td>
<td>-0.09</td>
<td>-0.08</td>
<td>-0.07</td>
<td>-0.08</td>
<td>-0.08</td>
<td>-0.01</td>
<td>--</td>
</tr>
<tr>
<td>10. Parent-rated Inattention</td>
<td>0.20</td>
<td>0.08</td>
<td>0.08</td>
<td>0.10</td>
<td>0.07</td>
<td>-0.03</td>
<td>-0.11</td>
<td>0.25</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

*Note. N = 77.*

<sup>a</sup>controlling for age and verbal IQ; <sup>b</sup>Speeded Reading (Sight Word Efficiency and Phonemic Decoding Efficiency);<br><sup>c</sup>Non-Speeded Reading (Word Identification and Word Attack)<br>*p < .05, ** p < .01
Table 11

*Partial Correlations*\(^a\) between number of RAN-digits named, Inattention, and Reading

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>1</th>
<th>2</th>
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<th>8</th>
<th>9</th>
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</thead>
<tbody>
<tr>
<td>1. RAN digits-10 items</td>
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<td></td>
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<tr>
<td>2. RAN digits-20 items</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>3. RAN digits-30 items</td>
<td>.79(^*)</td>
<td>.94(^*)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>4. RAN digits-40 items</td>
<td>.82(^*)</td>
<td>.94(^*)</td>
<td>.98(^*)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>5. RAN digits-50 items</td>
<td>.80(^*)</td>
<td>.93(^*)</td>
<td>.97(^*)</td>
<td>.99(^*)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>6. Speeded Reading(^b)</td>
<td>-.48(^*)</td>
<td>-.51(^*)</td>
<td>-.51(^*)</td>
<td>-.52(^*)</td>
<td>-.54(^*)</td>
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<tr>
<td>7. Non-Speeded Reading(^c)</td>
<td>-.36(^*)</td>
<td>-.40(^*)</td>
<td>-.40(^*)</td>
<td>-.40(^*)</td>
<td>-.40(^*)</td>
<td>.81(^*)</td>
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<tr>
<td>8. CPT II-omissions (inattention)</td>
<td>-.08</td>
<td>-.08</td>
<td>-.09</td>
<td>-.08</td>
<td>-.06</td>
<td>-.13</td>
<td>-.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. CPT II-Hit Reaction Time BC</td>
<td>.07</td>
<td>.02</td>
<td>.04</td>
<td>.02</td>
<td>.01</td>
<td>-.08</td>
<td>-.08</td>
<td>-.01</td>
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</tr>
<tr>
<td>10. Parent-rated Inattention</td>
<td>.03</td>
<td>.09</td>
<td>.03</td>
<td>.06</td>
<td>.07</td>
<td>-.03</td>
<td>-.11</td>
<td>.25(^*)</td>
<td>-.07</td>
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</tbody>
</table>

*Note.* \(N = 77\).

\(^a\)controlling for age and verbal IQ; \(^b\)Speeded Reading (Sight Word Efficiency and Phonemic Decoding Efficiency); \(^c\)Non-Speeded Reading (Word Identification and Word Attack)

\(^* p < .05. \(^{**} p < .01\)
### Table 12

*Partial Correlations*\(^a\) between number of RAN-colors named, Inattention and Reading

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>1</th>
<th>2</th>
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<th>8</th>
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<tbody>
<tr>
<td>1. RAN colors-10 items</td>
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<tr>
<td>2. RAN colors-20 items</td>
<td>.74**</td>
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<td></td>
</tr>
<tr>
<td>3. RAN colors-30 items</td>
<td>.70**</td>
<td>.93**</td>
<td>--</td>
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<tr>
<td>4. RAN colors-40 items</td>
<td>.64**</td>
<td>.88**</td>
<td>.95**</td>
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<tr>
<td>5. RAN colors-50 items</td>
<td>.62**</td>
<td>.86**</td>
<td>.92**</td>
<td>.97**</td>
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<tr>
<td>6. Speeded Reading(^b)</td>
<td>-.19</td>
<td>- .28*</td>
<td>-.32**</td>
<td>-.35**</td>
<td>-.34**</td>
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<td></td>
</tr>
<tr>
<td>7. Non-Speeded Reading(^c)</td>
<td>-.18</td>
<td>- .26*</td>
<td>-.30**</td>
<td>-.29*</td>
<td>-.28*</td>
<td>.81**</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>8. CPT II-omissions (inattention)</td>
<td>.13</td>
<td>.18</td>
<td>.15</td>
<td>.10</td>
<td>.10</td>
<td>-.13</td>
<td>-.22</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>9. CPT II-Hit Reaction Time BC (inattention)</td>
<td>-.01</td>
<td>-.04</td>
<td>-.02</td>
<td>-.06</td>
<td>-.06</td>
<td>-.08</td>
<td>-.08</td>
<td>-.01</td>
<td>--</td>
</tr>
</tbody>
</table>

*Note.* \( N = 77.\)

\(^a\)controlling for age and verbal IQ; \(^b\)Speeded Reading (Sight Word Efficiency and Phonemic Decoding Efficiency);
\(^c\)Non-Speeded Reading (Word Identification and Word Attack)

\(^p < .05, \quad \quad ** p < .01\)
### Table 13

*Partial Correlations\textsuperscript{a} between number of RAN-objects named, Inattention and Reading*

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>1</th>
<th>2</th>
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<th>7</th>
<th>8</th>
<th>9</th>
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</thead>
<tbody>
<tr>
<td>1. RAN objects-10 items</td>
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<td></td>
<td></td>
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<tr>
<td>2. RAN objects-20 items</td>
<td>.66**</td>
<td>--</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. RAN objects-30 items</td>
<td>.48**</td>
<td>.84**</td>
<td>--</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. RAN objects-40 items</td>
<td>.47**</td>
<td>.85**</td>
<td>.94**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. RAN objects-50 items</td>
<td>.48**</td>
<td>.82**</td>
<td>.90**</td>
<td>.97**</td>
<td>--</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>6. Speeded Reading\textsuperscript{b}</td>
<td>.05</td>
<td>-.24*</td>
<td>-.31**</td>
<td>-.31**</td>
<td>-.29**</td>
<td>--</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>7. Non-Speeded Reading\textsuperscript{c}</td>
<td>.04</td>
<td>-.15</td>
<td>-.22</td>
<td>-.22</td>
<td>-.20</td>
<td>.81**</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. CPT II-omissions (inattention)</td>
<td>.20</td>
<td>.20</td>
<td>.02</td>
<td>.13</td>
<td>.11</td>
<td>-.13</td>
<td>-.22</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>9. CPT II-Hit Reaction Time BC (inattention)</td>
<td>-.08</td>
<td>-.06</td>
<td>.04</td>
<td>-.02</td>
<td>.03</td>
<td>-.08</td>
<td>-.08</td>
<td>-.01</td>
<td>--</td>
</tr>
<tr>
<td>10. Parent-rated Inattention</td>
<td>.02</td>
<td>.07</td>
<td>.02</td>
<td>.03</td>
<td>.03</td>
<td>-.03</td>
<td>-.11</td>
<td>.25*</td>
<td>-.07</td>
</tr>
</tbody>
</table>

*Note. N = 77.*

\textsuperscript{a}controlling for age and verbal IQ; \textsuperscript{b}Speeded Reading (Sight Word Efficiency and Phonemic Decoding Efficiency); \textsuperscript{c}Non-Speeded Reading (Word Identification and Word Attack)

*p < .05, ** p < .01
items. For both RAN-letters and RAN-objects, there was a significant predictive advantage to naming more than one row. The results were therefore mixed in relation to what was hypothesized. It is apparent, however, that RAN is not functioning as a continuous performance task because longer versions of RAN were not consistently predictive of inattention and reading across all four tasks.

*Does rapid naming speed mediate the relation between Inattention and Reading Ability?*

Given that the overarching goal of this study was to determine if RAN tasks were assessing children’s inattention, the final hypothesis of the study was that RAN performance would mediate the link between inattention and reading ability. For this hypothesis to have been supported, four conditions needed to be met, as outlined by Baron and Kenny (1986). As can be seen in Table 8, there was no significant association between any of the four types of RAN (letters, digits, objects, or colors) and inattention as measured by the CPT II (i.e., omission errors, hit reaction time block change) and by parent-rated inattention, respectively. This first criterion was therefore not fulfilled and it was consequently not possible for RAN performance to serve as a mediator in the relation between inattention and reading outcomes.
CHAPTER 4
DISCUSSION

The primary purpose of this study was to determine if children’s naming speed (i.e., RAN) mediated the relation between inattention and their reading abilities. A number of previous studies have found no relation between RAN and ADHD (e.g., Ackerman & Dykman, 1993; Felton et al., 1987; Felton & Wood, 1989; Wood & Felton, 1994) whereas other studies have demonstrated that children diagnosed with ADHD perform significantly more poorly on RAN-objects and/or RAN-colors relative to controls (e.g., Carte et al., 1996; Nigg et al., 1998; Semrud Clikeman et al., 2000). This study expands the literature by focusing on inattention, the component of ADHD shown to be most strongly related to reading (e.g., Dally, 2006; Giannopulu et al., 2008; Willcutt & Pennington, 2000; Willcutt et al., 2000; Willcutt et al., 2005; Willcutt, Betjemann, et al., 2007; Willcutt, Pennington, et al., 2007). Results demonstrated that children’s naming speed was unrelated to parent ratings of inattention or CPT omission errors. Thus, naming performance did not serve as a mediator in the relation between inattention and word reading ability.

In contrast to the lack of a significant association between measures of inattention and RAN, CPT omission errors were significantly associated with phonological awareness. That is, children who made fewer CPT omission errors performed significantly better on the Phonological Awareness Composite (i.e., consisting of the Blending Words and Elision subtests), compared to those committing a greater number of CPT omission errors. It is interesting that the relation between phonological awareness and the CPT was specific to omission errors (i.e., inattention) in that commission errors (i.e., impulsivity) were not significantly associated with children’s phonological awareness. Although the significant association between phonological awareness and CPT omission errors was unexpected, it is consistent with McGee et al. (2000), who found CPT overall index scores to be significantly associated with phonological awareness. Dally (2006) similarly found a significant association between inattention and phonological awareness, as did Lonigan et al. (1999) within their preschool sample from low-income backgrounds. It may be that sustained attention is required.
for phonological-related success. This is a plausible explanation for the current findings in that children were required to listen carefully to an examiner when completing the Elision subtest or to an audiotape for the Blending Words subtest and then focus on the accurate manipulation of word sounds prior to responding. Results from this study consequently demonstrate that children’s attention has a greater impact in phonological awareness than in naming performance.

Children’s phonological awareness, as assessed by the phonological awareness composite, was significantly related to performance on the RAN-letters task, but not the RAN-digits task, contrary to what was hypothesized. Consistent with expectation, phonological awareness was unrelated to performance on either RAN-colors or RAN-objects. The obvious discrepancy in the relationship between phonological awareness and RAN-letters versus phonological awareness and RAN-digits is noteworthy because RAN digits and RAN letters were each uniquely predictive of reading performance. That is, to have determined that the phonological awareness composite was non-predictive of RAN-digits while simultaneously observing that RAN-digits were significantly predictive of reading suggests that RAN is contributing significant variance to reading independent of phonological awareness, as has been suggested by a large number of researchers (e.g., Byrne et al., 2006; Georgiou et al., 2008; Katzir et al, 06; Kirby et al., 2003; Manis et al., 1997; Misra et al., 2004; Powell et al., 2007, Tiu, Wadsworth, Olson, & DeFries, 2004) although not all researchers agree (e.g., Bowey et al., 2005; Savage, 2004; Torgesen et al., 1997; Torgesen et al., 1994).

As anticipated, RAN-letters and RAN-digits were each significantly associated with reading whereas neither RAN-colors nor RAN-objects were related to reading outcomes. These results replicate those within the research literature showing that the rapid naming of letters and digits rather than the rapid naming of objects and colors is most predictive of reading outcomes in children older than age six (e.g., Bowers et al., 1988; Compton, 2003b; Cornwall, 1992; Spring and Capps, 1974; Wolf et al., 1986). The current findings are consistent with Schatschneider et al., (2002) who found RAN to be predictive in populations of average readers. Other studies, however, have failed to demonstrate a relation between RAN and reading within normal reading populations (e.g., McBride-Chang and Manis, 1996; Meyer et al., 1998). In general, stronger RAN-reading relations are found in samples of relatively poorer readers (e.g., Compton, 2003b; Wagner et al., 1997; Walsh, Price, & Gillingham, 1988; although see Swanson, Trainin, Necoechea, & Hammill, 2003). The present significant relation between RAN and
reading is consequently noteworthy given the significantly stronger than average language and naming abilities of this community sample. In regard to the specific amount of variance accounted for within reading, however, RAN letters and digits contributed approximately 15% variance to reading, a result consistent with Scarborough’s (1988) meta-analysis demonstrating RAN contributes an average 14% variance to reading outcomes. It was necessary to have determined that naming ability was predictive of reading performance within this sample population before exploring if there was a role for inattention in understanding the relation between naming performance and reading ability.

Because the measures of inattention were not related to RAN measures in hypothesized ways, it is important to examine whether the measures of inattention adequately indexed the construct. Previous studies have reported that measures of inattention are significantly related to measures of reading (e.g., Willcutt & Pennington, 2000; Willcutt et al., 2000; Willcutt, Betjemann, et al., 2007; Willcutt, Pennington et al., 2007). In this study, parent ratings of inattention were not significantly predictive of reading outcomes. This was surprising given prior studies have shown a relation between reading and inattention, as assessed by parent and/or teacher ratings (e.g., Giannopulu et al., 2008; Willcutt, Pennington, et al., 2007). Dally (2006) similarly found no association between parent-rated inattention and reading although she found that teacher ratings of inattention were significantly predictive of children’s reading ability. Although not utilized in this study, teacher ratings of inattention may have been stronger predictors of reading outcomes given teacher ratings have been shown to be superior to parent ratings in the identification of young children at risk for learning difficulties (e.g., Taylor, Anselmo, Foreman, Schatschneider, & Angelopoulos, 2000). Teacher ratings of behavior are also typically more reliable than parent ratings at the preschool, child, and adolescent age levels (Reynolds & Kamphaus, 1992, as discussed in Kamphaus et al., 2007).

Examination of the CPT indices of inattention provided mixed evidence for measuring the intended construct of inattention. Consistent with studies that have shown a relation between inattention and reading (e.g. Dally, 2006; Giannopulu et al., 2008; Willcutt, Pennington, et al., 2007), the CPT omission errors index was significantly predictive of non-speeded reading. However, neither of the CPT indices of inattention was associated with speeded reading. Beyond its association with measures of reading, there was evidence of convergent and discriminant validity for the CPT indices. CPT omission errors demonstrated cross-measure convergent
validity in that CPT omission errors were significantly correlated with parent-rated inattention. Evidence of discriminant validity was obtained by the finding that CPT omission errors were not significantly correlated with parent-rated hyperactivity/impulsivity. However, discriminant validity was poor for both CPT omission errors (i.e., inattention) and parent-rated inattention as both of these indices correlated with measures of hyperactivity/impulsivity. That is, CPT omission errors correlated significantly with CPT commission errors (i.e., which assessed hyperactivity/impulsivity) and parent-rated inattention was significantly correlated with parent-rated hyperactivity/impulsivity.

Overall, the evidence was mixed concerning the measurement of the construct of inattention in this study. Although some of the expected patterns of associations between measures of inattention and measures of reading were obtained with some measures (i.e., omission errors were significantly correlated with non-speeded reading), others were not (i.e., parent-rated inattention was not significantly correlated with speeded or non-speeded reading). Moreover, the patterns of associations between indices of inattention and indices of hyperactivity/impulsivity provided mixed support for the measurement of the inattention construct in this study. Because findings concerning the relation between inattention and reading outcomes have been reported more consistently when teacher ratings are used to index children’s inattention, it is likely important to examine whether the failure to obtain the hypothesized relations between measures of inattention and measures of RAN in this study were the result of how attention was measured. However, if it were found that teacher attention is uniquely associated with reading outcomes--either directly or mediated via RAN measures--it will be important to identify the reasons for the unique relation between teacher ratings of inattention, relative to other measures of inattention, and reading-related skills.

Whereas no support was demonstrated for a relation between inattention and naming in the current study, one necessary consideration is whether the present sample characteristics influenced this result. That is, could the restricted range within this community sample have made it impossible to observe a relation between inattention and naming which might otherwise exist? This explanation seems implausible in that sufficient variability existed within the sample to observe a relation between naming performance and reading ability and between CPT II omission errors and parent-rated inattention. That is, if there was adequate variability within the
sample population to find this pattern of associations and inattention was unrelated to naming, the relation between naming and reading is likely about something other than inattention.

Although the total number of RAN items named was not associated with children’s attention, RAN-letters and RAN-digits functioned differently in regard to how the number of items named influenced the strength of the RAN-reading relationship. For RAN-digits, the naming of one row of symbols, or 10 stimuli, was equivalent to the naming of 50 symbols in the prediction of both speeded and non-speeded reading. For RAN-letters, the naming of more than 30 symbols was advantageous in the prediction of both speeded and non-speeded reading. It is unclear what accounts for this discrepancy, but part of the explanation may relate to the variability of children’s performance on RAN-digits versus RAN-letters (i.e., $SD = 13.25$ versus $SD = 11.47$, respectively). It may be that a relatively greater number of RAN-letters stimuli must be named before reliable differences in performance emerge between participants. Consistent with this, the RAN-letters task may be functioning as a speeded letter identification task, with successively longer versions of RAN-letters representing a more reliable predictor of performance on actual reading tests.

This approach to rapid naming is relatively novel in that very few researchers have examined how length of RAN impacts the predictive utility of RAN. It has never been established, for example, what minimum number of RAN symbols must be named to effectively predict reading. Compton, Olson, DeFries, and Pennington (2002) were among the first to question the impact of varying the parameters of the serial RAN task. These researchers compared the difference in predictive utility between traditional 50-item RAN-letters or RAN-digits tasks and an alternative version of RAN-letters or digits in which participants were required to name as many items as possible within a 15-second time span. Compton et al. (2002) found the 15-second alternative version of both the RAN-letters and RAN-digits tasks to be significantly more predictive of word level reading compared to the traditional 50-item tasks. It was unclear to Compton et al., however, why each of the 15-second alternative tasks demonstrated a significant predictive advantage over the 50-item traditional RAN tasks. Results from the current study demonstrated some consistency with Compton et al. in that RAN-letters and RAN-digits tasks were found to demonstrate predictive utility when fewer than 50 items were named; although unlike Compton et al., there was no predictive advantage to naming fewer
than 50 items. Others have similarly shown the 15-second version RAN to be predictive of reading (e.g., Davis et al., 2001; Huslander et al., 2003; Tiu et al., 2004).

Overall, although it is ultimately important to understand why performance differences exist within or between RAN tasks, important contributions are made to the literature simply by exploring RAN in such a manner that these differences can be identified. In the case of the current study, for example, the discrepancy in findings between RAN-letters and RAN-digits suggests that researchers may gain greater value in examining these tasks independently, rather than grouping them together and incorrectly assuming that they are operating similarly in the prediction of reading.

Limitations

There were some limitations to this study. First, participants were recruited from public schools within an upper middle-class community and demonstrated significantly stronger performance on naming and language measures compared to children in the general population. More specifically, children in the sample scored significantly higher on all four rapid naming measures (i.e., RAN-letters, RAN-digits, RAN-objects, and RAN-colors) as well as the Elision, Word Identification, Word Attack, Sight Word Efficiency, Phonemic Decoding and Stanford-Binet Vocabulary tasks, relative to normative groups. Participants’ attention, however, was found to be consistent with the general population. Despite being skewed toward the upper end of the language and reading ability curve, naming ability was predictive of reading performance, thus replicating well-established findings within the naming literature and suggesting these findings will likely generalize to children with more typical language abilities.

The recruitment of a community sample represented both a strength and weakness within this study. There are advantages to utilizing community samples, as the results can more readily be applied to the general population (e.g., Goodman et al., 1997). In addition, the inclusion of both male and female participants was a strength, relative to naming-related studies that have restricted their participant recruitment to males (e.g., Carte et al., 1996; Halperin et al., 1991; Nigg et al., 1998). The use of a non-clinical population, however, meant there was less variability within measures and this may have contributed to attenuated correlations and thus fewer significant findings relative to what may have been found if a clinical population would have been contrasted with a control group. Consistent with this, the strength of the relation between naming and reading appears to change as a function of a sample’s level of reading.
development, with stronger predictive relations typically observed within poorer samples of readers (e.g., Compton, 2003b; Wagner et al., 1997) although a meta-analysis by Swanson et al. (2003) concluded the opposite. Future researchers utilizing community samples may choose to first dichotomize children on the attention variable and then determine how participants high versus low on attention fare relative to one another on naming and reading and also examine how these various measures relate to one another. In addition, it would be useful to explore these same research questions within clinically diagnosable samples to determine if the findings differ from those of community samples.

A second limitation relates to power. One hundred and one participants were recruited for the study based on an a priori power analysis that suggested that a minimum of 84 participants were required to achieve sufficient power. Although data from 94 subjects contributed to each of the hierarchical analyses, several of the correlational analyses included as few as 77 participants. This is likely not a problem but it is possible that data from an additional seven participants may have impacted analyses slightly. As well, given that some of the CPT indices (e.g., hit reaction time block change) have demonstrated relatively poor reliability, it is possible that this reduced reliability contributed to attenuated correlations between inattention and naming and between inattention and reading outcomes.

Measurement issues with the DIBELS Phoneme Segmentation task as well as the hit reaction time block change index of the CPT represent a third limitation. The DIBELS Phoneme Segmentation task demonstrated poor predictive utility because children with better reading performance took significantly longer to sound out phonemes than less able readers. Thus, the better a child was at segmenting, the weaker their performance on the Word Attack, Word Identification, Sight Word Efficiency, Phonemic Decoding, and Nonsense Word Fluency tasks. Observations during testing revealed that children who tended to perform well on the majority of language measures tended to be overly cautious (and hence slow) when responding to the timed Phoneme Segmentation Fluency Task. The DIBELS Phoneme Segmentation Task was not intended for use with children beyond grade one but was utilized within the current study because it represented a speeded measure of phonological skill. The goal of utilizing speeded and non-speeded versions of both phonological and reading tasks was to rule out the contribution of shared method variance to outcomes. However, a review of phonological awareness measures (e.g., Sodoro, Allinder, & Rankin-Erickson, 2002; Yopp, 1988) did not reveal any speeded tests
that could be utilized with participants beyond first grade. Thus, pilot testing was initiated and sufficient variability was demonstrated across longer versions of each of the DIBELS measures (i.e. none of the pilot participants reached ceiling).

The CPT hit reaction time block change index similarly failed to function in the manner anticipated as it was unrelated to any other assessed variable. As described above, the hit reaction time block change measure is calculated by computing the slope of change in reaction times across the six time blocks and may reflect a decrease in vigilance across the CPT, if there is one, according to Conners (2000). Thus, it was anticipated this index would tap “sustained attention” and would be significantly correlated with parent ratings of inattention and CPT omission errors, which are presumed to reflect sustained attention. Although there have been concerns related to its low reliability, this index has been capable of differentiating between ADHD and non-clinical groups (e.g., Conners, 2000). Ultimately, although scores on CPT hit reaction time block change index were normally distributed, they fell within an extremely limited range (i.e., $SD = .03$) and this may have contributed to a lack of significant findings. CPT omission errors, in comparison, demonstrated relatively greater variability (i.e., $SD = .40$) and this may have contributed to their significant association with parent ratings of inattention. An alternative perspective, however, is to view the present findings as consistent with those of Collings (2003) who demonstrated that decrements in sustained attention are specific to ADHD-combined type and not ADHD-primarily inattentive type. Given this, there would be no reason to anticipate significant associations between the CPT hit reaction time block change index and omission errors and parent-rated inattention, respectively.

Conclusions and Future Directions

Findings from this study provide a unique contribution to the literature by demonstrating that RAN performance did not serve as a mediator in the link between inattention and reading outcomes even when children’s attention is assessed directly by means of a CPT. Despite concerns about the higher than average language and reading abilities of study participants and the associated concern regarding attenuated correlations within community samples, children’s naming was found to be predictive of their reading performance, and inattention played no role in this association. Thus, it may be most sensible to focus research efforts on evaluating other viable explanations for the RAN-reading relationship. A variety of opinions and associated research foci exist regarding the hypothesized underlying constructs of RAN, some of which
were reviewed above. One view is that RAN and word reading share a phonological component (e.g., Wagner & Torgesen, 1987). Another view is that RAN represents a measure of orthographic processing (e.g., Bowers & Wolf, 1993a; Bowers & Wolf, 1993b). Yet a different perspective is that general processing speed accounts for the robust relation between naming and reading (e.g., Denckla & Cutting, 1999; Shanahan et al., 2006; although see Powell et al., 2007). The naming literature continues to be divided, however, about each of these as well as other theoretical constructs underlying the predictive utility of RAN.

Neurobiological research represents a useful avenue for increasing our understanding of the RAN-reading relationship and ultimately enhancing our knowledge regarding which theoretical constructs might best explain naming. A number of researchers have utilized structural MRI and found significant discrepancies between dyslexics and controls across a number of brain regions (e.g., Eliez et al., 2000; Hynd et al., 1995; Leonard et al., 1993; Pennington et al., 1999). Hynd et al. (1995), for example, demonstrated that the genu of the corpus callosum is significantly smaller in children diagnosed with dyslexia as compared to normal controls. Furthermore, these researchers found moderate correlations between reading achievement and the relative size of the genu and splenium. More specific to naming, Misra et al. (2004) utilized functional magnetic resonance imaging to demonstrate that different areas of the brain were activated in adult females during the naming of RAN-letters versus RAN-objects. Misra et al. further suggested that letter naming should not be considered a phonological task, based upon their neurobiological findings. Eckert et al. (2003) compared dyslexics and controls in grades four through six and found that RAN was the only reading-related measure to be consistently significantly associated with the anatomical differences (i.e., size of right cerebellar anterior lobe; right pars triangularis and cerebral brain volume) that differentiated dyslexic from control participants. Collectively, neurobiological studies provide important clues about the specific constructs underlying RAN by highlighting the psychophysiological correlates of rapid naming. These correlates, in turn, can be utilized in the evaluation of the different theoretical positions that have been put forth in the area of rapid automatized naming. Thus, partnerships between reading researchers and neuroscientists should be encouraged, as this will allow for continued advancement of our knowledge base pertaining to RAN-reading relations.

Finally, to achieve a full understanding of naming, future research should aim to identify the specific aspects of naming which are most predictive of reading outcomes. Although most
naming researchers employ Denckla & Rudel’s (1976) RAN task, participants have alternatively been instructed to name columns rather than rows (e.g., McBride-Chang, 1996; McBride-Chang & Manis, 1996), name uppercase rather than lowercase letters (e.g., Bowey et al., 2005), or name stimuli that are presented in a one-line horizontal display (Bowers et al., 1988; Brock & Christo, 2003; Brock & Knapp, 1996; Davis et al., 2001). The CTOPP rapid naming tasks (Wagner et al., 1999) and the 15-second version of RAN, as described above, represent additional naming methodologies. It is consequently challenging to determine which components of RAN are most predictive given this variation in RAN-related demands across studies. Further, Compton (2003a) has demonstrated that relatively minor changes to RAN stimuli can significantly impact outcomes. That is, Compton substituted one of the five stimuli within the RAN-letters matrix to a more visually versus phonologically similar letter, and determined that although the visual change had the largest impact on naming speed, phonological substitutions had the greatest impact on reading outcomes. Findings such as these highlight the need for comprehensive studies that improve our understanding of how specific components of rapid naming contribute to reading outcomes. It would be worthwhile to administer multiple versions of RAN within the same study, for example, to determine how these different formats impact reading performance. A greater emphasis on component skills within naming studies will ultimately contribute to a more refined understanding of RAN-reading relationships.
APPENDIX

APPROVAL LETTER AND CONSENT FORMS

Florida State University

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2783
(904) 644-6933 · FAX (904) 644-4392

APPROVAL MEMORANDUM

Date: 3/19/2004

To:
Brent (Bloomfield) Cantor
3951 SW Canby Street
Portland Oregon 97219

Dept.: PSYCHOLOGY DEPARTMENT

From: John Tomkowiak, Chair

Re: Use of Human Subjects in Research
Understanding reading in elementary school children

The forms that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Human Subjects Committee at its meeting on 3/10/2004. Your project was approved by the Committee.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals which may be required.

If the project has not been completed by 3/9/2005 you must request renewed approval for continuation of the project.

You are advised that any change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must promptly report, in writing, any unexpected problems causing risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is IRB00000446.

cc: Christopher Lonigan
    HSC No. 2004.147
The Florida State University
Tallahassee, Florida 32306-1270
Department of Psychology
850/644-2040
850/644-7399 (fax)

Informed Consent Form

Project Title: Understanding Reading in Elementary School Children
Investigators: Brenlee Cantor, M.Sc.; Christopher J. Lonigan, Ph.D.
Telephone: (212) 429-1375

I HAVE BEEN INFORMED THAT:

Brenlee Cantor, M.Sc., who is a graduate student at Florida State University, and Christopher J.
Lonigan, Ph.D., who is a professor at Florida State University, have requested my child’s participation
in a research study to be conducted at my child’s school. The purpose of this study is to learn more
about some of the predictors of children’s reading performance.

If I consent to my child’s participation in the study, I will be requested to complete a brief rating form
regarding my child’s attention.

My child’s participation will involve participating in two testing sessions, each approximately 25
minutes in length, within a three-week period. Children will be tested in a quiet room within their
school during school hours and an effort will be made to avoid removing my child from the classroom
during important lessons.

During one of the testing sessions, children will be asked to play a long computer game where they
must respond to letters being flashed up on the screen in front of them. During the other testing
session, children will be asked to complete reading-related tasks like read words, sound out words as
letters are removed, name digits, letters, colours, and objects, and describe things (e.g. “what is a
tree?”). Children will also complete a couple of word-find activities for fun.

Before beginning testing with my child, my child’s permission will be obtained. It will be made clear
to my child that he/she has the right to withdraw from the study at any time.

All information collected will be strictly confidential, to the extent allowed by law. No individual
child or family will ever be identified publicly. Names are removed from all information gathered on
my child and replaced with identification numbers. The information obtained from this study will be
kept in a locked file storage area and will not be released to my child’s school or to any other person in
a way that would reveal the identity of my child. In public reports of the results of this study to my
child’s school or in professional communications, results that have been averaged over large numbers
of children are reported and in a way that insures the anonymity of all participants.

My child’s permission is completely voluntary. If I do not give permission for my child to participate,
or if my child does not want to participate once I have consented to his/her participation, it will not
affect his/her grade. Similarly, my child or I may change our minds and withdraw from this study at
any time. There are no foreseeable risks or discomforts if I agree to my child’s participation in this study.

Although there may be no direct benefits to my child, the possible benefits of my child’s participation in this research study are that the information that is gathered will help us better understand children’s reading. This will inform us regarding effective ways to intervene and prevent reading disabilities in children and thus, help them to have better lives overall.

Any questions I have concerning the research study or my child’s participation in it, before or after my consent, will be answered by Brenlee Cantor at 404-137-3 or brenlee.cantor@comcast.net

I have read the above informed consent form. I understand that I may withdraw my consent and discontinue my child’s participation at any time without penalty. In signing this consent form, I am not waiving any legal claims, rights, or remedies. My signature below indicates that I have decided to allow my child to participate. A copy of this consent form will be offered to me upon my request.

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Committee, Institutional Review Board, Florida State University, through the Vice President for the Office of Research at (850) 644-8633.

Child’s Name: ___________________________ Child’s Birthdate: ________________

Child’s Teacher’s Name: ___________________________

Parent/Guardian Name: ___________________________ Date: ________________

I PERMIT MY CHILD TO PARTICIPATE:

Parent/Guardian Signature

I DO NOT WANT MY CHILD TO PARTICIPATE:

Parent/Guardian Signature

I WOULD LIKE TO KNOW THE GENERAL RESULTS FROM THIS RESEARCH PROJECT. PLEASE SEND INFORMATION TO:

Name: ___________________________

Address: ___________________________

______________________________
Child Assent and Experimental Instructions for Understanding Reading in Elementary School Children

(After entering the experimental room): “I’d like your help in a study that I’m doing. I’ve come to your school with a bunch of activities and games. Some of the things you’ll probably find really fun, some of the things you might find kind of boring. I’ve done these things with kids from other schools and now want to see how kids in your school do, and what you think of the things I’ve brought along. I’m going to be asking most of the other kids in your class to do the same activities with me. I’d like to do some things with you today, and I’d like to come back another day and do some different things.”

(continue on with one of the two scripts below, depending on whether the first session is focused on Conners Continuous Performance Task or Multiple Language Tasks)

- If session one is Multiple Language tasks, continue: “I’m going to ask you to name some things and will also ask you to read some words. Some of the words that I’m going to ask you to read are for older kids and you may not know how to read them. That’s okay, just try your best. And if you don’t want to read any more words, you just let me know and we can stop at anytime. You won’t get into any trouble and nobody will be mad at you. Okay? So will you help me with my study?”

- If YES: “Great, before we get started, I’m going to ask you to write your name here on this sheet of paper, saying that you understand what we just talked about. This sheet of paper says”,

“I have been told that my mom or dad has said that it’s okay for me to participate, if I want to, in a project about children’s reading. I know that I can stop at any time that I want to and that will be okay.”

Name: ___________________________

- Okay, let’s get started. I might write stuff down some of the time, because I don’t want to forget what you’re saying. Sometimes I might have this timer going, so I can see how long it takes kids in your school to do things. Okay, are you ready for me to explain the first activity?”

- Provide instructions and sample items for RAN tasks, Phonological Awareness Tasks, Reading Tests, and DIBELS tasks prior to administering each of these measures. 1-2 word-find activities will also be administered for fun.

- If NO: “Okay, that’s okay. I’ll walk you back to your classroom.” (thank them, and accompany them back to the classroom).
REFERENCES


BIOGRAPHICAL SKETCH